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BULLETIN NUMBER 16

SALMON OF THE NORTH PACIFIC OCEAN

PART IX

COHO, CHINOOK AND MASU SALMON IN OFFSHORE WATERS

1. COHO SALMON, by Harold Godfrey
2. CHINOOK SALMON, by James E. Mason
3. MASU SALMON, by Shoichi Tanaka

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VANCOUVER, CANADA, 1965

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INTERNATIONAL NORTH PACIFIC FISHERIES COMMISSION

Established by Convention between Canada, Japan
and the United States for the Conservation of the
Fisheries Resources of the North Pacific Ocean

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PREFACE

The International North Pacific Fisheries Commission is publishing in its bulletin series a comprehensive report entitled *Salmon of the North Pacific Ocean*, the various parts of which are described in Bulletin No. 12. The purpose of this comprehensive report is to present the results of research on salmon (*Oncorhynchus* spp.) conducted since 1955 under an extensive program designed by the Commission and executed by research organizations of the three countries which established the Commission—Canada, Japan and the United States. The various parts are being published out of numerical order, each part being published as it is completed by the joint-reporting team assigned to its preparation.

The present bulletin contains Part IX of *Salmon of the North Pacific Ocean*. It consists of reports on the life history and offshore distribution of coho, chinook and masu salmon on the high seas of the North Pacific Ocean, each species report having been prepared separately by a member of a joint-reporting team responsible for this part of the comprehensive report. Although the reports on each species were not written jointly, they have all been reviewed and commented on by each author.

Prior to publication, manuscripts must receive the approval of three editorial referees and the members of the Commission. The editorial referees for Japan, Canada and the United States are Tasuku Hanaoka, Peter A. Larkin and Donald L. McKernan, respectively. Bulletins of the Commission are published separately in English and Japanese. The original language of each paper is indicated and accuracy of translation is the responsibility of the Secretariat.

WILVAN G. VAN CAMPEN
INPFC Secretariat.

SALMON OF THE NORTH PACIFIC OCEAN

PART I. INTRODUCTION AND CATCH STATISTICS FOR NORTH PACIFIC SALMON

PART II. REVIEW OF OCEANOGRAPHY OF THE SUBARCTIC PACIFIC REGION

PART V. OFFSHORE DISTRIBUTION OF SALMON

PART IX. COHO, CHINOOK AND MASU SALMON IN OFFSHORE WATERS

SALMON OF THE NORTH PACIFIC OCEAN—PART IX COHO, CHINOOK AND MASU SALMON IN OFFSHORE WATERS

1. COHO SALMON IN OFFSHORE WATERS

by

Harold Godfrey, Fisheries Research Board of Canada
Biological Station, Nanaimo, B.C., September 1963

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INTRODUCTION

On the Pacific Coast of North America, the coho salmon (*Oncorhynchus kisutch*) occurs from at least as far north as Cape Thompson in the Chukchi Sea (Smith, 1960) south to streams that are tributary to Monterey Bay, California (Briggs, 1953). In Asia, the latitudinal distribution of this species is rather

similar; coho salmon are found at least as far north as the Anadyr River and occur in mainland streams southward to the Amur Firth, and on the Shantariskii Islands and the islands of Sakhalin and Hokkaido (Gribanov, 1948; Hikita, 1956; Sano, 1959; Shmidt, 1950). On both continents they are found in considerably smaller numbers towards the northern and southern limits of their distribution.

Coho salmon are produced in numerous small coastal streams as well as in the tributaries of larger rivers. This characteristic renders the assessment of coho stocks and the management of coho fisheries extremely difficult.

On the North American continent, the region of the coho's greatest abundance extends from central Alaska to the State of Washington; in Asia, it is along the east and west coasts of the Kamchatka Peninsula.

Various Soviet workers have noted that the coho salmon has been neglected by coastal commercial fisheries in the U.S.S.R. until very recent years. The main reason for this is that the coho enter inshore waters late in the season, when the major fisheries for the more abundant chum, pink and sockeye salmon are ending, and at a time of deteriorating weather. Also, in the rivers themselves, coho salmon are apparently more difficult to capture than the other species by the weirs and nets which the villagers use. Since 1952, large numbers of coho salmon have been taken annually by the Japanese high seas salmon fishery in the western North Pacific, principally off the southeast coast of Kamchatka. Important numbers are also taken each year in the Japanese land-based fishery which operates eastward of Hokkaido and the southern Kuril Islands. Tagging experiments and other evidence indicate that these fish are principally of U.S.S.R. origin, primarily from the coasts of Kamchatka and the Okhotsk Sea.

In North America, the exploitation of the coho salmon has been at a very high level for many years,

TABLE 1. Average catches, for 1954–1959, of Pacific salmon taken in coastal fisheries and on the high seas.

	Total	Sockeye		Chum		Pink		Coho		Chinook	
		No.	%	No.	%	No.	%	No.	%	No.	%
Asia (millions of fish)	162.4	12.6	7.8	40.4	24.9	105.4	64.9	3.9	2.4	0.1	0.1
North America (millions of fish)	66.7	17.3	25.9	9.7	14.5	30.4	45.6	6.2	9.3	3.2	4.8
U.S.S.R. (1,000 metric tons)	124.7	3.6	2.9	48.9	39.2	66.4	53.2	4.9	3.9	0.9	0.8
Japanese mothership, Pacific Ocean (1,000's of fish)	37,044	9,526	25.7	12,865	34.7	12,364	33.4	2,235	6.0	56	0.2
Japanese mothership, Bering Sea (1,000's of fish)	<i>Av. 1957 and 1959</i> 11,663	3,585	30.7	1,458	12.5	6,581	56.4	16	0.1	24	0.2
	<i>In 1956</i> 6,648	2,209	33.2	4,310	64.8	76	1.1	5	0.1	48	0.7
Japanese mothership, Okhotsk Sea (1,000's of fish)	9,213	329	3.6	2,728	29.6	5,990	65.0	166	1.8	1	—
Western Alaska (1,000's of fish)	7,306.5	5,959.0	81.6	660.5	9.0	446.8	6.1	85.7	1.2	154.5	2.1
Central Alaska (1,000's of fish)	17,273.9	2,599.8	15.1	3,182.3	18.4	10,953.3	63.4	472.2	2.7	66.3	0.4
Southeast Alaska (1,000's of fish)	14,592.9	975.3	6.7	2,660.7	18.2	9,419.6	64.5	1,203.8	8.2	333.5	2.3
British Columbia (million pounds)	143.9	32.2	22.4	34.7	24.1	40.7	28.3	22.7	15.8	13.3	9.2
Washington (1,000 metric tons)	22.0	7.5	34.2	2.3	10.3	4.8	21.6	3.8	17.2	3.7	16.8
Oregon (1,000 metric tons)	4.6	0.1	2.6	0.9	2.0	—	0.2	1.2	25.7	3.2	69.5
California (1,000 metric tons)	3.8	—	—	—	—	—	<.1	0.2	4.3	3.6	95.7
Research vessels—											
1955–1960 (1,000's of fish)											
Japan	93.6	36.7	39.2	29.5	31.6	20.3	21.7	6.6	7.1	0.5	0.5
United States	43.7	14.0	32.1	22.8	52.1	5.8	13.3	0.7	1.7	0.3	0.8
Canada	9.8	4.2	43.0	3.4	35.2	1.5	15.5	0.6	6.2	—	0.1
Combined	147.1	54.9	37.3	55.8	37.9	27.6	18.8	7.9	5.4	0.8	0.6

particularly in British Columbia and the State of Washington. In more northern areas, such as western Alaska, coho salmon are fished commercially less intensively and, as in some regions of the U.S.S.R., this is partly associated with their late arrival during autumn weather and at the termination of the major salmon fisheries. Also, in some areas of western Alaska, coho are fished extensively in fresh water for personal consumption. However, no catch data are available.

In recent years, and primarily in British Columbia and the State of Washington, sport fishing for coho salmon has assumed considerable importance in the overall exploitation of this species. It has become necessary to impose increasingly severe restrictions upon both kinds of fisheries in order to ensure the maintenance of present levels of abundance through adequate escapements.

Some appreciation of the relative importance of the coho salmon, on both continents, as compared with the other species, can be gained from the figures shown in Table 1. (In preparing this table, it was not possible to be consistent in the use of either catch by weight or catch by number of fish, because of differences between regions in methods of statistical compilation.) At the present time, coho salmon con-

stitute only a minor proportion of the total commercial salmon catches in Asia and North America. During 1954–1959, coho provided about 2.4 percent of the total Asian salmon catches (including those of the Japanese high seas fisheries) and 9.3 percent of the North American catches, as measured by number of fish. By weight, the contributions of coho would be somewhat higher, because they are heavier fish, on the average, than the pink and sockeye salmon. In certain North American areas, coho salmon are of much greater importance. By weight, they constituted about 16, 17 and 26 percent of the total commercial salmon catches in British Columbia, Washington and Oregon, respectively.

Much of the research on which this report is based was focussed on the problem posed by the Protocol to the International Convention for the High Seas Fisheries of the North Pacific Ocean. That problem was to study the intermingling in the high seas of salmon stocks of North American and Asian origin and to determine the proper location for a line or lines which would “equitably divide” those stocks.

Although coho salmon may be of minor importance in the North Pacific Ocean, as compared with sockeye, chum and pink salmon, they do occur in sufficient numbers in some areas to deserve consideration in any

deliberations pertaining to an "equitable division" of salmon stocks on the high seas. However, because they do present less urgent problems in this connection they have been studied less intensively, so that there are considerable gaps in our knowledge of the occurrence of coho salmon in offshore waters. In particular, there is little or no positive information on the racial origin of coho taken in high seas localities—identification by scale, serological, parasitological and morphological techniques has not been pursued. Despite this, however, it is hoped that, on the basis of what information there is available, it will be possible to describe in this paper the distribution of coho salmon in the North Pacific Ocean and to indicate their status as it pertains to the problems of the Protocol.

In addition to the references actually cited, many unpublished United States, Japanese and Canadian tagging and gillnetting records, arising from research conducted under the cooperative program of the International North Pacific Fisheries Commission (INPFC), have been used in preparing this report. The only published record of tagging studies conducted under the INPFC program is Hartt (1962), which describes United States tagging during 1956–1958.

LIFE HISTORY

Many of the facts upon which this report is based have been taken from two published works on the life history of the coho salmon—in the U.S.S.R., that by Griбанov (1948), mainly for coho in Kamchatkan rivers; and in North America, that by Shapovalov and Taft (1954), with particular reference to the coho of Waddell Creek in California. This statement is made in order to circumvent over-frequent reference to these papers.

SPAWNING AND INCUBATION

On both continents coho salmon spawn in numerous small coastal streams and in the tributaries of larger rivers. Their return to coastal waters is very prolonged and occurs late in the season, after the sockeye and pink salmon, and mainly during late July and August. According to Griбанov (1948), intensive entry into a river is associated with the beginning of a rising tide and schooling off the mouth of a river, in brackish water, occurs during the period of falling tide. They ascend the rivers during both rising and falling water levels, but cease movement during peak floods. They move upstream mainly during daylight hours (see also Neave, 1943).

Over the range of the species, the spawning period is very protracted, but spawning takes place mainly during November-January in North America, and in October-November in Kamchatka. Coho spawning as late as March has been reported on both continents.

More or less distinct "summer" and "autumn", or "autumn" and "winter" runs of coho have been described for certain Kamchatkan stocks, but less definitively so for North American stocks.

In Kamchatka, coho spawning grounds are distributed throughout the whole extent of the river basins, beginning at tidal influence and extending to headwaters, frequently beyond the upstream limits of the sockeye, pink and chum salmon. In these respects the spawning grounds of coho in North America are generally similar in smaller streams, but various authors ascribe as characteristic of the coho salmon the fact that, generally speaking, they do not ascend larger rivers as far as do the chinook and sockeye salmon, and seldom beyond 150 miles above the river mouth.

Coho spawning usually occurs in swifter water than is characteristic for sockeye salmon (Griбанov mentions surface water velocities of 0.30–0.50 m/sec for coho and pink salmon, as compared with 0.10 m/sec for sockeye), and usually in riffles or where there is ground seepage. The ground water that is typical of coho spawning beds is usually highly oxygenated. However, exceptions in the way of relatively low surface water velocities, weak bottom waterflow, oxygen deficiency and silting in redds have also been noted (Andrew and Geen, 1960; Smirnov, 1960).

The proportions of the two sexes among the returning adults are usually nearly equal, but variations do occur in the sex composition during the upstream migration and throughout spawning. In North America, various authors have noted the preponderance of males early in the run, and of females later. Griбанov has observed the predominance of males on the spawning beds, which he attributed to the briefer survival of females after spawning. Competition between several males for a single female has often been observed.

Throughout the range of coho salmon distribution, spawning occurs over a wide band of water temperatures. Griбанov has reported water temperatures in Kamchatkan rivers during spawning as low as 0.8°C and as high as 7.7°C (as the annual variation in average temperature in these rivers is not great, these values do not describe the limits for this species).

The female coho salmon may make three or four egg depositions, each in separate redds which she digs herself. Under normal conditions, almost all the eggs ejected lodge in the nest and are properly buried. The fecundity of the female coho salmon is relatively high as compared with the other species. Average egg counts for Kamchatkan salmon are: chinook, 8254; sockeye, 3763; chum, 2544; coho, 4883 (Gribanov); and pink, 1300–2200 (Semko, 1939). For possibly smaller coho in several small British Columbia creeks, average egg counts have ranged from 2100 to 2789 (Wickett, 1951; Foerster, 1944). Several workers have observed a relationship between the size of female coho and the number of eggs. The relationship determined by Shapovalov and Taft was: number of eggs = $0.01153 \times \text{fork length}^{2.9403}$; the longest length class averaged 76 cm and 3300 eggs. The degree of fertilization under natural conditions is usually very high.

It has been noted on both continents that the full period of incubation, and the time for development to different stages, varies with the average water temperatures on the redds. At Waddell Creek, coho eggs hatched in from 38 days, at an average temperature of 11°C, to about 48 days, at an average temperature of 9°C. Gribanov quotes 100–115-day incubations under natural conditions in a Kamchatkan stream and from 86–101 days in a hatchery with an even temperature of 4.5°C.

Emergence from the gravel usually begins in from two to three weeks after hatching, with peak emergence occurring within three weeks. Complete emergence may take up to ten weeks. Free-swimming, newly-emerged coho fry have been observed from early March to late July.

STREAM LIFE AND DOWNSTREAM MIGRATION

Almost all young coho salmon spend a year or more in streams or lakes before they migrate to sea. Small numbers may proceed to sea as fry.

Following emergence, the young fish first take up residence in shallow gravel areas not far from their redds, especially near the stream banks, where they feed avidly and grow rapidly. At first they tend to congregate in schools, but as they grow these schools break up and the fish disperse both up and down the stream. Gribanov has recorded that they may move upstream considerable distances into a lake at no great time after their emergence, and at sizes of only 38–45 mm in length.

Based upon experiments in aquaria and from observations in natural streams, Chapman (1962) concluded

that coho fry were aggressive and territorial or hierarchical in behaviour. Hierarchies and territories were organized on the basis of fish size, and smaller fish tended to move downstream upon continuous harassment by the larger. Chapman termed such fry “nomads”, as distinct from the larger “residual” fry which, because of their size and aggressive behaviour, were able to maintain territories after emergence.

Following the peak of their emergence, there is a marked decline in their numbers, which has been attributed primarily to predation by fishes.

As they grow, they move into deeper waters and eat coarser food. During the winter months, feeding declines and growth becomes negligible. Gribanov considers the time of formation of the first winter rings on the scales to be February–May for coho in Kamchatkan streams.

The downstream migration of the coho smolts takes place over a considerable period of time, but probably mainly from April to August. The timing varies between localities, and there are also annual variations which, according to Shapovalov and Taft, are associated with stream conditions. Gribanov observed the migration in the Paratunka River to take place from the end of May to the end of August, with the peak occurring in July. At Waddell Creek, the main migrations took place during April and May, but some migrants were found almost all the year round. The impetus for the migration of the smolts appears to be associated with their size, age and such ecological conditions as water levels and amount of flow. Shapovalov and Taft have suggested that the larger fish are the first to migrate. Although some fish may move downstream by day, the main migrations occur at night (Neave, 1943), particularly under flood conditions.

At the time of migration, one-year-old coho smolts in Waddell Creek averaged from 103 to 117 mm in fork length. Gribanov concluded that it is the smaller one-year-old fish that remain in the streams a second year before migrating to sea.

OCEAN RESIDENCE

Until recent years, it was generally believed that coho salmon, unlike the sockeye, pink and chum salmon, did not make extensive ocean migrations, but that most spent the duration of their marine life in coastal waters. In estuarine waters off Kamchatka, young coho salmon have been found up to five to six months after they had entered the sea. During this time they had grown considerably. Upon this, Gri-

banov argued that since the matures at the time of their spawning migration were not much larger, and since the full period of ocean residence involved only nine to ten additional months, it would follow that it must be almost impossible for coho salmon to make extensive migrations away from the coasts. Furthermore, in past years, many immature coho salmon have been tagged in coastal waters of North America and recovered the following year in the same foraging areas, or in spawning rivers. The known migrations of these fish seldom exceeded 300 miles, and were usually considerably less, and were always restricted to inshore waters. For these reasons, it has been concluded that while in the sea most coho salmon probably remain close to shore.

In more recent years, information derived from the Japanese high seas salmon fisheries, and from the observations of Japanese, United States and Canadian research vessels, has made it clear that numerous coho, and possibly most, do migrate far into the North Pacific, to distances that require long return migrations to the coasts of their origin, during their last months in the sea.

In British Columbia, juvenile coho salmon have been taken in shallow coastal waters, frequently off island beaches, as late as mid-September. However, already by the end of July catches had declined sharply, suggesting that during late July and August they had moved off into deeper water (unpublished data of Manzer and Taylor, 1955 and 1956, Biological Station, Nanaimo, B.C.). The sizes of these fish varied considerably, not only by time, but also by fishing location, suggesting racial differences and/or differences in the timing of emergence and downstream migration. On August 19, 1955, 15 coho taken off the east coast of Vancouver Island had attained an average length of approximately 24 cm, and a weight of about 166 g. In a more northerly area, near the Skeena River, on August 15, 1955, 27 juvenile coho averaged 20 cm in length and 175 g in weight. Juvenile coho captured off the southeast coast of Kamchatka in the month of September had reached lengths of 23.1–31 cm (average, 26.5 cm), and weights of 141–440 g (average, 236 g), according to Piskunov (1955). Piskunov also noted that fish that had spent only one year in fresh water showed greater length and weight increments for the period they had spent in the sea than those that had remained in fresh water a second year. Small juvenile coho have been taken in late July and early August in the Okhotsk Sea off the West Kamchatkan coast. Among a small sample of these, the modal fork length was 26 cm (Fisheries Agency of Japan, 1962).

Milne (1950) has indicated that there are probably two distinct types of coho in British Columbia, which may be referred to as "ocean" and "inshore" types. The former are believed to spend most of the period of their ocean residence in outer coastal or offshore waters, whereas the latter remain within inside waters (such as Georgia Strait and Puget Sound) at all times. The ocean type is faster growing, and certain evidence suggests that this more rapid growth begins in fresh water and continues through the marine phase. Both groups of fish were of the same freshwater age.

As described in more detail in another section, coho salmon may disperse far out into the North Pacific. Asian coho salmon have been tagged as far to the east as about 175°W longitude, in Aleutian waters, or almost 1000 miles eastward of where they were recovered later in the same year. Western Alaskan coho have been taken at similar distances to the west. In the Gulf of Alaska, a mature coho was tagged as far as about 700 miles westward from where it was recovered. An immature coho that was recovered in the following year off Depoe Bay, Oregon, had been tagged some 1200 miles to the northwest in the Gulf of Alaska. It was tagged in September, at which time it had already reached a length of 31 cm. Other immature coho had exhibited similar long migrations during their first months in the sea.

The main masses of Asian coho would appear to be distributed well to the south in the western North Pacific during the spring and early summer, and do not enter waters north of 45°N latitude until during mid and late summer. North American coho have not been found in similar large concentrations in offshore waters, but they, too, probably winter well to the south and move into more northerly waters of the Gulf of Alaska and the eastern North Pacific distinctly later than do the sockeye and chum salmon, and possibly even somewhat later on the average than the pink salmon.

Available evidence, from commercial fisheries and research vessels, indicates that in the sea coho salmon occur most frequently near the surface. Individuals have been taken at greater depths, but most coho have been caught in the upper 10 m. Juvenile coho taken by Piskunov (1955) off southeast Kamchatka were also most abundant within the same depth range.

Maturing coho have been taken in ocean waters where the surface temperatures have ranged at least from 4.0°C to 15.2°C; best catches by INPFC research vessels have occurred within the approximate

range of 8–12°C. However, various evidence indicates that coho may also occur in even colder waters, and Griбанov has even found them under the ice of a brackish lagoon in southeast Kamchatka.

RETURN TO COASTAL WATERS

In the western North Pacific, large concentrations of coho salmon appear off the southeast coast of Kamchatka mainly during late July and August. Their entry into coastal waters and off river mouths on the East Kamchatkan coast is prolonged and extends from mid-July to September or October. It is somewhat later farther north (for example, in the Anadyr Gulf), and along the West Kamchatkan and the Okhotsk-Tauisk coasts (Griбанov, 1948; Semko, 1954; Moiseev, 1955). According to Sano (1959), the coho runs to several Hokkaido streams extend from late September to early October.

The coho that return to the east coast of Kamchatka and farther north approach the southern tip of the peninsula over a broad front, apparently from well to the south and southeast, and also along the south side of the Aleutian Chain (some from at least as far east as about 175°W longitude). Some enter the Bering Sea first, through the western Aleutian passes. Those that spawn in streams along the West Kamchatkan and Okhotsk-Tauisk coasts approach the northern Kurils and southeast Kamchatka from a similar direction in the North Pacific and enter the Okhotsk Sea through the Kuril passes and the Kuril Strait.

Coho salmon first arrive in appreciable numbers in coastal waters of central and southeast Alaska and British Columbia early in July, and the runs extend into late August or September. They appear to be somewhat later farther south, at least off the Washington coast. Few details are known regarding the times of arrival of coho off western Alaskan streams, except that again they are late in the season and follow the runs of the sockeye and pink salmon.

The direction of movement from the high seas of returning North American coho is not yet clear, but recent Canadian researches have added some information (Neave *et al.*, 1962). In the early spring and summer of 1962, maturing coho began to move into the Gulf from a southeast direction. An area of concentration built up in the center of the Gulf during late June, following which the coho apparently dispersed towards the coasts in many directions, since tagged coho were subsequently recovered at points extending from the Alaska Peninsula to the Strait of Juan de Fuca. Considerable tagging in coastal

waters of southeast Alaska and British Columbia has shown that the adult coho do not make extensive migrations along the coast as do the chinook salmon. Rather, their migrations are relatively short and may be in many directions inward to coastal streams (Milne, 1957). Tagging has shown the presence of western Alaskan coho south of the Aleutian Islands to as far west as about 176°W longitude.

The rate of migration of maturing coho salmon at sea is difficult to determine with accuracy because most tagged coho have been recovered in rivers or streams which they entered at an unknown time before they were caught. Milne (1957) considered that coho in coastal waters travelled more slowly than chinook salmon and probably wandered more during both feeding and spawning migrations. However, rates of as high as roughly 30 miles a day over a long distance have been recorded for some individuals, and many workers have referred to the strong swimming ability of the coho as compared with the other Pacific salmon. The apparent slow rate of migration of coho in the sea may be due to continued and intensive feeding activity until toward the end of their migration.

AGE, SIZE AND GROWTH

Almost all coho salmon, on both continents, spend one or two years in fresh water before migrating to sea. That is, they make the seaward migration in the spring or summer following emergence, or a year later. Also, most spend two growing seasons in the ocean, returning late in the year following that in which they entered the sea. These fish may be designated for age as 3_2 and 4_3 fish, indicating that they had entered the sea in their second or third year of life, and returned in the following year (by Griбанov's designations these would be 2_1+ and 3_2+ , respectively).

In some areas, besides the 3_2 and 4_3 adults, significant numbers of "precocious" males return late in the same year they went to sea; these would be classed as 2_2 fish. Various other ages have also been applied to very minor numbers of coho, including fry that made the seaward migration during the same season as emergence. (For many references to coho ages, besides Griбанov, and Shapovalov and Taft, see also Foerster, 1955, and Wilimovsky and Freihofer, 1957.)

Among the two major age groups, the predominance of one over the other varies geographically. According to Griбанov's determinations of some years ago (1926–1936), 4_3 fish were predominant along the east

TABLE 2. The age composition of coho salmon taken in British Columbia fisheries in early and recent years (from Milne, Biological Station, Nanaimo, British Columbia; unpublished data).

Area	Year	Ages								Number read
		2 ₁	2 ₂	3 ₁	3 ₂	3 ₃	4 ₁	4 ₂	4 ₃	
British Columbia—Troll (Pritchard, 1940)	1927-1930	7	7	11	6179	2	4	46	54	6312
	Percent	0.1	0.1	0.2	97.9	—	0.1	0.7	0.9	100.0
Quatsino (Neave, 1951)	1949	—	—	—	—	—	—	—	—	—
	Percent	—	2.0	—	95.0	—	—	3.0	—	100.0
Georgia Strait—Troll	1952-1959	19	8	5	1248	—	—	5	—	1285
	Percent	1.5	0.6	0.4	97.1	—	—	0.4	—	100.0
West coast of Vancouver Is. —Troll	1952-1959	23	—	10	1697	—	—	7	3	1740
	Percent	1.3	—	0.6	97.5	—	—	0.4	0.2	100.0
Fraser River—Gillnet	1957-1959	15	—	4	563	—	—	1	—	583
	Percent	2.6	—	0.7	96.5	—	—	0.2	—	100.0

TABLE 3. Age composition of adult coho salmon from various localities in Asia and North America (from Sato, 1961a).

			2 ₂		3 ₂		3 ₃		4 ₂		4 ₃		5 ₂		5 ₃		Total no.
			No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
<i>North America</i>																	
1.	Ketchikan R.	1955	0	0	17	70.8	0	0	0	0	7	29.2	0	0	0	0	24
2.	Stikine R.	1955	0	0	47	45.2	0	0	1	1.0	54	51.9	0	0	2	1.9	104
3.	Cook Inlet R.	1956	0	0	8	40.0	0	0	0	0	12	60.0	0	0	0	0	20
4.	Yukon R.	1956	0	0	10	55.6	0	0	0	0	8	44.4	0	0	0	0	18
5.	Unalakleet R.	1955	0	0	25	37.9	0	0	0	0	41	62.1	0	0	0	0	66
6.	Nome R.	1956	0	0	5	29.4	0	0	0	0	12	70.6	0	0	0	0	17
<i>Asia</i>																	
7.	Kamchatka R.	1957	0	0	28	54.9	0	0	0	0	23	45.1	0	0	0	0	51
	Kamchatka R.	1958	3	6.3	24	50.0	0	0	0	0	21	43.8	0	0	0	0	48
8.	Bolshaia R.	1957	0	0	19	65.5	0	0	1	3.4	8	27.6	0	0	1	3.4	29
	Bolshaia R.	1958	0	0	86	96.6	0	0	0	0	3	3.4	0	0	0	0	89
	Bolshaia R.	1959	0	0	55	72.4	0	0	0	0	21	27.6	0	0	0	0	76
9.	Kukhtui R.	1959	0	0	22	32.8	0	0	0	0	45	67.2	0	0	0	0	67

coast of Kamchatka, and 3₂ fish along the west. However, since 1959, according to Dr. S. Tanaka of the Japanese Fisheries Agency (personal communication) there has been an increase in the proportion of 4₃ fish in West Kamchatka. Gilbert (1913) indicated that in North America the proportion of 4₃ fish increased from south to north reaching a ratio of about 60:40 in the Yukon River. More recently, Shapovalov and Taft's age determinations for Waddell Creek coho indicate an average of 18.3 percent 2₂ males and 81.7 percent 3₂ males and females for the years 1933-1942; more than 95 percent of British Columbia coho are 3₂ fish, and all but a few go to sea as year-old smolts (Table 2; Foerster, 1955). Sato's recent age determinations of some Asian and North American coho indicate the occurrence of year-class fluctuations in various streams and also suggest that in

more northern areas the 4₃ fish may equal or exceed in abundance the 3₂ fish (see Table 3).

According to Gribov's data, mature Kamchatkan coho averaged 60 cm in fork length (range, 40-87 cm) and 3.5 kg (about 7.7 lbs) in weight (range, 1.5-6.5 kg). Males were longer and heavier than females. There were regional differences in average size that were due to differences in age composition, but there were also variations among a single age class from several localities which Gribov attributed to differences in rates of growth.

The average fork lengths for mature Waddell Creek coho were given as 40.6, 64.7 and 63.9 cm for the 2₂ males, the 3₂ males and the 3₂ females, respectively; and males tended to be consistently larger than females.

Coho salmon taken in the troll fisheries of British Columbia exhibited a monthly increase in size, indicating a continuance in growth throughout the fishing period of from June to September. As an example, during 1952–1960, the average lengths of coho taken on the west coast of Vancouver Island changed from 54.6–58.8 cm in June to 64.4–69.8 cm in September, an increase of roughly 10 cm (Milne, unpublished data). The average seasonal weight of coho taken in all British Columbia commercial fisheries during 1952–1961 has been 7.09 lbs or 3.22 kg (range, 6.15–8.09 lbs, or 2.79–3.67 kg).

With the exception of pink salmon, the rate of growth of coho salmon during the ocean phase exceeds that of the other species. An illustration from Shapovalov and Taft (their Fig. 21) indicates that 3_2 coho from Waddell Creek reach an average length of roughly 10–15 cm at the time they migrate to the sea; during their ocean life of 15–16 months duration they increase in length by about 51.5 cm, an increase over their freshwater length of more than 400 percent. According to Gribanov's data, Kamchatkan coho of age 3_2 exhibit a similar rate of increase in length during their marine life. The rate of growth of the 4_3 fish during the second year of life in fresh water is but a small fraction of that of the second year of life of the 3_2 fish, which is spent in the sea. However, during their one year in the sea the rate of growth of the 4_3 fish accelerates sharply, so that during their fourth year of life their growth is similar to that of the 3_2 fish in their final year.

HOMING AND STRAYING

As with the other Pacific salmon, it is believed that the great majority of adult coho return to the streams in which they were hatched. Also, although some straying undoubtedly does occur, it is probably to nearby streams rather than to more distant rivers. The most positive evidence that supports these hypotheses comes from marking experiments. In the case of coho salmon, Shapovalov and Taft present data relating to the return of marked coho salmon to Waddell and Scott Creeks over a period of seven return-seasons, during 1934–1941. Of fish marked (by fin-clipping) at Waddell Creek, 85.1 percent of the recovered adults were taken in Waddell Creek and 14.9 percent in Scott Creek (which is only 4–3/4 miles away). Of those marked at Scott Creek, 73.2 percent of the recoveries were taken there and 26.8 percent in Waddell Creek. Straying to more distant streams was not positively demonstrated, but for obvious practical reasons it could not be investigated thoroughly. It appeared that the rate of straying was fairly consistent in different years among fish of the same

year class. This, according to Shapovalov and Taft, suggested that the degree of straying was determined prior to the time of return to a stream, probably at the time of ocean migration. In this connection they noted that the greater the number, and the smaller the size, of the downstream migrants, the greater was the amount of straying.

Various other investigations involving the return of marked coho salmon also offer supporting evidence to their homing behaviour (for example, Neave, 1941; Foerster and Ricker, 1953), including a long series of experiments with marked hatchery-reared coho at Minter Creek, Washington (Salo and Bayliff, 1958). In addition, there have been a number of instances where coho eggs have been transplanted for rearing in streams where the species was not indigenous, and to which the adults have subsequently returned.

Although the established return of adult fish to the natal streams constitutes evidence supporting the homing hypothesis, more complete proof depends upon whether the degree of straying was negligible. This is most difficult to determine, particularly in the case of the coho salmon, whose spawning streams are so many and so widely dispersed. At the present time, it may be said that although doubtless some "straying" by coho salmon does occur, no extant evidence indicates that it is as nearly significant as the degree of "homing" in the case of marked fish, or that under natural conditions the return of coho salmon bears no geographical relationship to the streams in which they were hatched. Indeed, the perpetuation of known stocks, and their continued absence or paucity in certain streams, indicate the opposite; certainly, the management of coho salmon fisheries and stocks, as with the other salmon species, is based upon the assumption that most of the progeny return to parental streams.

FOOD

The young coho fry begin to feed actively immediately after emergence from the gravel. According to Gribanov, they may do this even while they carry remains of the yolk sac, but Shapovalov and Taft state that under natural conditions at Waddell Creek coho fry rarely emerge until the yolk sac is absorbed. The principal food of fry consists of aerial insects, followed by aquatic larval insects, mainly chironomids.

When they have grown larger, young coho in fresh water feed extensively on small fishes, in addition to insects and other material, including the fry of the other species of Pacific salmon. They are considered,

in fact, to be among the most serious predators of young salmon, even of their own kind (Ricker, 1941 ; Semko, 1954 ; Hunter, 1959 ; Roos, 1960).

The food of coho salmon in the sea has not been studied extensively, particularly during the early stages of their rapid growth. Young coho taken in Petropavlovsk Bay had fed mainly on insect larvae and imagoes, crustaceans and fish fry ; and in a sample from Kronotski Gulf, fish fry were particularly important (Synkova, 1951). Piskunov (1955) refers to the importance of larger forms of zooplankton in the food of young coho in the sea. The marine food of the older and larger coho is mainly fishes of various kinds, according to Griбанov, and their importance has also been noted by Synkova. Adult coho taken in the Gulf of Alaska by Canadian research vessels in 1957 and 1958 had eaten a variety of organisms, including squid and fish, euphausiids, amphipods, copepods, decapods and chaetognaths ; squid and fish, followed by euphausiids, appeared to be the most important items (Manzer and Neave, 1958 ; 1959).

MORTALITY AND SURVIVAL

By the nature of their wide distribution in numerous streams, coho salmon as a species are particularly vulnerable to some of the natural phenomena that condition their freshwater environment, and to many of the effects of the encroachments of civilization. The capacities and qualities of streams may be seriously impaired by fire, flood and drought, through logging, by water diversion for irrigation and hydro-electric development, by road construction and by industrial and agricultural pollution. On the other hand, certain features of the biology of the coho salmon would seem to favour their survival—their dispersed distribution, which probably lends to the species a resilience against such stresses as have been mentioned ; their late return to the rivers, which is usually at a time when water levels are more favourable for upstream migration and spawning ; their aggressive behaviour, including that as predators of other young salmon ; and (according to Smirnov, 1960) there may even be features of their reproductive processes that enhance their chances of survival under adverse conditions and that are not possessed to the same degree by the other species.

Prior to spawning, adult coho salmon mortality in fresh water arises from river obstructions or adverse water levels that prevent or delay migration, or render actual spawning difficult or impossible. Because of their wide distribution, particularly in numerous small streams, coho salmon have been less seriously affected than the other species by the installation of large

power dams. Log jams and similar obstructions are probably frequent occurrences in the type of streams which the coho inhabit. An example of a large rockslide which blocked the upstream movement of coho salmon in the Babine River (the main tributary of the Skeena River, British Columbia) may be mentioned (Godfrey *et al.*, 1954). This slide affected the salmon runs to that river in 1951 and 1952. The other species, and particularly the sockeye salmon, were seriously affected by prolonged delay and injury. However, coho losses were much lighter, mainly because by their later migration they reached the site of the slide when water levels and other stream conditions were considerably more favourable.

Studies of the survival of coho salmon in fresh water, from egg to migrating smolt, are not extensive. According to both Griбанov and Shapovalov and Taft, the percentage of eggs that are successfully fertilized is very high and rather constant. Smirnov (1960) has referred to the large quantity of seminal fluid and the large concentration of spermatozoa in the seminal fluid which distinguish the male coho. He relates these features to the character of the spawning sites of the coho and to their loose concentration on the spawning grounds—redds usually built separately and in a fast current, as compared with sockeye, which usually spawn in quieter water and as part of a great concentration of fish.

Based upon the examination of numbers of redds, Griбанov estimated that the mortality of coho eggs under natural conditions usually does not exceed four to six percent, but that instances as high as 60 percent and, less frequently, total losses do occur. Although lacking adequate quantitative data, Shapovalov and Taft concluded that in Waddell Creek the survival under favourable conditions was probably between 65 and 85 percent of the eggs deposited. In both instances, silting is referred to as the primary agent causing losses. Smirnov ascribes to the coho egg and embryo certain features which relate to their adaptability to develop and grow under conditions of declining oxygen concentration—small eggs with relatively thin shells, a dense surface capillary system, an abundance of carotinoid pigment and intensive pulsation of the embryo.

As mentioned earlier, after the peak of emergence has passed there is a marked decline in the number of fry, which Shapovalov and Taft have attributed to predation by fishes.

Estimates of the survival of young coho during their freshwater existence are few and variable and are probably not representative of the overall situation for

TABLE 4. Estimates of the survival of coho salmon from five streams in North America, in percentages.

Location	Egg to smolt			Number of years	Smolt to adult			Number of years	Egg to adult			Number of years
	Max.	Min.	Av.		Max.	Min.	Av.		Max.	Min.	Av.	
Hooknose Creek ¹⁾	3.961	0.703	1.299	10	20.24	6.71	11.79	7	0.472	0.106	0.146	7
Nile Creek ²⁾	2.10	0.76	1.27	4	—	—	—	—	—	—	—	—
Minter Creek ³⁾	9.65	0.70	1.71	11	9.38	0.91	5.20	9	0.905	0.015	?	—
Eel River ⁴⁾	—	—	—	—	56.9	15.8	35.6	12	—	—	—	—
Waddell Creek ⁵⁾	1.56	1.16	1.43	4	7.72	0.98	3.55	4	0.30	0.02	0.13	6

¹⁾ Hunter; unpublished data, Biological Station, Nanaimo, B.C.

²⁾ Wickett (1951).

³⁾ Salo and Bayliff (1958).

⁴⁾ Murphy (1952); this is for ocean survival during last year of life only.

⁵⁾ Shapovalov and Taft (1954).

coho salmon on the two continents. Gribanov presents no data pertaining to this phase. Neave (1949) has estimated the production of fry from potential egg depositions in two streams on Vancouver Island, British Columbia. In 12 determinations, values ranged from 11.8 to 40.0 percent, with an overall average of 22.8 percent. This average value is high as compared with estimates reported for pink and chum salmon at a similar stage of development; Neave attributed this to more stable conditions of stream flow and bottom materials and less crowding on the redds. He considered that the large losses were due to predators, particularly the cutthroat trout.

A number of estimates have been made of the freshwater survival of coho salmon from potential egg deposition to migrating smolts for two streams in British Columbia (Hooknose and Nile Creeks), one stream in the State of Washington (Minter Creek) and one in the State of California (Waddell Creek). The data are summarized in Table 4. The rates ranged from a low of 0.70 percent to as high as 9.65 percent. The averages for the four streams, based upon a varying number of estimates in each, were rather similar. They ranged from 1.27 to 1.71 percent. These values are somewhat similar to a number of estimates made for several stocks of sockeye salmon at a similar stage in their life history, to which Foerster (1955) gave a geometric mean of 1.43 percent. However, for Chilko Lake (Fraser River) sockeye, higher survival rates, varying between 2.3 and 3.2 percent, have been recorded (International Pacific Salmon Fisheries Commission, 1955).

A few attempts have been made to estimate the ocean survival of coho, but these have included the effects of fishing as well as natural mortality (Table 2). The low average rates resulting at Minter and Waddell Creeks (5.20% and 3.55%) as compared with Hook-

nose Creek (11.79%) were probably due in part to the fact that in those two streams some of the annual estimates were based upon the return of smolts marked by fin-clipping, since such rates were lower than those determined from unmarked fish.

Murphy (1952) has estimated the survival (after both natural and fishing mortality) in their last year of ocean life of coho salmon of the Eel River, California, on the basis of the numbers of two-year-old male and three-year-old male and female fish of the same brood returning in consecutive years. Assuming a 50:50 sex ratio of seaward migrants, and that the mortality of males and females in the ocean and in the stream until they were counted was equal, he obtained 12 estimates that ranged from 15.8 to 56.9 percent, average 35.6 percent.

The fishing mortality rate for coho salmon is not known with accuracy in any area of both continents, and because of the characteristics of their coastal migrations and spawning distribution it is virtually impossible to determine. Milne (1962) has tentatively estimated that in British Columbia somewhat less than 50 percent of the adults escape the fisheries to spawn. Too little is known from other areas to permit reliable statements, but it may be added that in the more northern areas of both continents the coho are somewhat "protected" from intensive fisheries because they arrive late in the season, when the main effort for the more abundant species has ceased, and when worsening weather restricts continued exploitation.

COHO SALMON STOCKS IN ASIA AND NORTH AMERICA

Accurate estimates of the magnitudes of either Asian or North American coho stocks are virtually impossi-

ble to determine, mainly because of the lack of anything approaching adequate escapement figures. As was indicated early in this report, the assessment of spawning escapements of coho salmon is extremely difficult, primarily because they are so widely dispersed in numerous streams and partly because their late arrival during autumn weather adds further obstacles to the task of enumeration.

The total number of streams in which coho salmon spawn is not known accurately, in either Asia or North America, but it undoubtedly amounts to many hundreds or even thousands. Furthermore, unlike the other species, and particularly the chinook and sockeye salmon, the contributions in the aggregate of all these streams are important in the total production of coho salmon, rather than the total production being subscribed to primarily by the contributions of a few major streams. In British Columbia, for example, Milne (1962) has estimated that something in the order of 2.5 million coho salmon spawn in more than 1,000 streams; no one area is dominant in their production and the top 10 rivers (1%) contribute less than 10 percent of the total escapement.

Because of these limitations, the relative sizes of the stocks of Asian and North American coho salmon will be described in terms of the annual catches of recent years in the different fishing regions of the two continents and in the Japanese fisheries on the high seas.

ASIAN COHO STOCKS

As will be described later, the coho salmon that are taken in the Japanese mothership and landbased fisheries are probably almost wholly of U.S.S.R. origin, although it is possible that some North American fish may be included. Such catches will therefore be apportioned to Asian coho stocks.

In Asian coastal waters, the great bulk of the commercial catch of coho salmon is taken along the east and west coasts of Kamchatka. Commercial catches are also made in the Okhotsk-Tauisk region and small numbers are taken in the Shantarski area, off Sakhalin, the Kuril Islands and Hokkaido (Gribanov, 1948; Moiseev, 1955). Available statistics give only the catches in East and West Kamchatka. The U.S.S.R. catch from East and West Kamchatka over the past twelve years, 1950–1961, has ranged from 2,300 (in 1950) to 7,500 (in 1954) metric tons, averaging 4,326 metric tons annually (Table 5). In numbers of fish, this approximates 760,000 to 2,400,000, with an average for the twelve-year period of about 1,415,000 coho.

TABLE 5. Commercial catch of coho salmon by the U.S.S.R., 1950–1961, by district, in metric tons and calculated numbers of fish¹⁾.

Year	Total		East Kamchatka		West Kamchatka	
	Metric tons	1000's of fish	Metric tons	1000's of fish	Metric tons	1000's of fish
1950	2,300	759	1,400	475	900	284
1951	2,700	880	1,200	407	1,500	473
1952	4,600	1,507	2,400	814	2,200	693
1953	6,500	2,106	2,400	814	4,100	1,292
1954	7,500	2,433	2,900	984	4,600	1,449
1955	6,300	2,038	2,200	746	4,100	1,292
1956	3,800	1,248	2,100	712	1,700	536
1957	5,200	1,699	2,500	848	2,700	851
1958	2,800	929	1,900	645	900	284
1959 ²⁾	3,807	1,230	1,243	422	2,564	808
1960	1,890	626	1,280	434	610	192
1961 ²⁾	4,520	1,523	2,350	858	2,110	665
Average	4,326	1,415	1,989	680	2,332	735
Average (1954–61) ³⁾	4,477	1,466	2,059	706	2,411	760

¹⁾ From Kasahara (MS 1962), converting to numbers of fish at 6.5 lbs per fish for East Kamchatka and 7 lbs per fish for West Kamchatka (using Table 31 of Kasahara, MS 1962).

²⁾ Kasahara (MS 1962) also shows catches of 111 and 60 metric tons from the Okhotsk coast in 1959 and 1961, respectively.

³⁾ The first major Japanese mothership fishery in the North Pacific Ocean and Bering Sea took place in 1954. The 1954–1961 average catch in the U.S.S.R. is thus considered to be the more appropriate figure to use for indicating the recent level of Asian coho stocks in terms of the annual catches.

In most years since 1950, the catches on the coast of West Kamchatka have been somewhat larger than along East Kamchatka and the West Kamchatkan catch has averaged 2,332 metric tons or 735,000 fish during these years, as compared with 1,989 metric tons or 680,000 fish in East Kamchatka. In West Kamchatka, catches considerably larger than average were made during 1953–1955 and, although a similar trend is evident for East Kamchatka, the catches on that coast have been more uniform.

Coho catches in the Japanese mothership fisheries from 1952 to 1961 are shown in Table 6. The first two years of operation were more or less exploratory. The average catch for 1954–1961 is 1,919,000 fish (a considerable reduction from the 1954–1960 average of 2,153,000, because of the very small catch in 1961). Peak catches of between 3.4 and 3.9 million fish were made in 1955, 1956 and 1958, with the catches in the other years being only about a third or considerably less than those.

Coho salmon are also taken in the Japanese land-

TABLE 6. Catch of coho salmon by the Japanese mothership fishery, by region, in thousands of fish, 1952–1961¹⁾.

Year	Total	Pacific Ocean	Bering Sea	Okhotsk Sea
1952	24	24	—	—
1953	340	340	—	—
1954	1,398	1,398	—	—
1955	3,576	3,184	—	392
1956	3,875	3,753	5	117
1957	442	339	1	102
1958	3,393	3,342	—	51
1959	1,423	1,391	32	—
1960	962	958	4	—
1961	284	284	*	—
Average (1954–61) ²⁾	1,919	1,831	—	—

¹⁾ From Kasahara (MS 1962); division between Pacific Ocean and Bering Sea is approximate.

²⁾ This average is used for reasons similar to those explained in a footnote in Table 5.

* Less than 500 fish.

based longline and driftnet fisheries, but in almost all the available statistics the catches are combined with those of chum, sockeye and chinook salmon. Landings of coho salmon during 1958–1961 in the offshore landbased driftnet fishery in the western North Pacific south of 48°N latitude are available and were as follows (from Kasahara, 1962—Table 42) :

Year	Metric tons	Estimated numbers in 1,000's (at 5.5 lbs per fish)
1958	1,962	786.0
1959	2,958	1,185.9
1960	3,362	1,347.9
1961	3,632	1,456.1
Average	2,978	1,194.0

Thus, in recent years, since the first major operation of the Japanese mothership fishery in 1954, the average total commercial catch of coho salmon that may be considered to be of Asian origin has been in the order of 4.6 million annually (U.S.S.R. coastal—1.5 million; Japanese mothership—1.9 million; Japanese offshore driftnet—1.2 million).

In considering these figures, it should be borne in mind that certain factors probably render them less reliable for purposes of defining the relative magnitude of the total U.S.S.R. coho stocks than would be the case with the catch statistics for the chum, pink and sockeye salmon. In the first place, the fishing effort of the Japanese high seas fisheries, in respect of coho salmon, has been very inconsistent from year to year. This is particularly so because in some years there has

been little or even no fishing at all during August, the period during which coho salmon reach their peak of abundance in waters off southeast Kamchatka. Also, some considerable variability in coho catches in the mothership fishery probably results from the fact that the fishing gear and the fishing effort are directed primarily to the catching of the more numerous species—and their abundance changes from year to year. Furthermore, because the coho arrive very late in the season in U.S.S.R. coastal waters and streams, during worsening weather and when the major fisheries are terminating, they probably tend to be fished both less intensively and with a more variable year-to-year effort. However, lacking further information, the figure of 4.6 million must be accepted as the best approximation of the present total average annual catch of Asian coho salmon, to be used as a measure of the relative magnitude of Asian coho stocks for comparison with those in North America.

NORTH AMERICAN COHO STOCKS

In western North America, the commercial fisheries for coho salmon are restricted by local regulation and international agreement to coastal and inshore waters. The principal fisheries extend from central Alaska to Oregon. California contributes a small catch, and small numbers of coho are also taken in western Alaska, mainly in Bristol Bay and along the Alaska Peninsula. As in some parts of the U.S.S.R., fishing for coho salmon in western Alaska may be limited by reason of their late return.

The North American commercial catch of coho salmon, by area, is shown in Table 7 for the period 1950–1961. The total catch was very constant over those 12 years, averaging 6,467,000 fish annually (1954–1961 average of 5,839,000). British Columbia invariably made larger catches than the other areas and averaged almost three million fish annually. Southeast Alaska and the State of Washington had similar average catches of 1.4 and 1.1 million fish, while much smaller catches, averaging 0.5 million or considerably less, were made in central Alaska, Oregon, western Alaska and California, in that order.

In some regions of the Pacific Coast of North America, particularly in British Columbia and the State of Washington, considerable numbers of coho are caught annually in the local sport fisheries which operate in more sheltered waters. Because of this, it is necessary to combine the sport catches of coho salmon with the commercial catches in order to determine the total annual take of the species. However, due to a number of factors, it is not possible to obtain very accurate statistics for sport catches, particularly by species, so

TABLE 7. Commercial catch of coho salmon in North America, by region, in thousands of fish, 1950-61¹⁾.

Year	Total North America	Western Alaska	Central Alaska	Southeastern Alaska	British Columbia	Washington	Oregon	California
1950	7,104	83	762	1,652	2,700	1,407	400	100
1951	10,107	76	645	3,310	4,053	1,323	600	100
1952	7,557	70	617	1,746	2,746	1,852	432	94
1953	6,119	31	387	1,163	2,894	1,269	301	74
1954	5,960	59	679	1,771	2,445	722	231	53
1955	6,184	27	468	1,338	2,970	1,043	290	48
1956	6,566	52	495	935	3,050	1,434	529	71
1957	6,513	87	301	1,217	3,137	1,108	576	87
1958	5,807	193	459	955	2,990	994	204	12
1959	5,644	76	332	1,094	2,897	988	222	35
1960	3,938	66	618	721	2,030	288	145	18
1961	6,103	67	357	889	3,297	1,035	370 ²⁾	88 ²⁾
Average	6,466.8	73.9	510.0	1,399.3	2,934.1	1,121.9	358.3	65.0
Average (1954-61)	5,839.4							

¹⁾ From Kasahara (MS 1962).

²⁾ Using a conversion factor of 7 lbs per fish.

that the figures that are available, as presented here, must be considered as approximations only.

Although many thousands of persons engage annually in ocean sport fishing for salmon along these coasts, the catch is not proportionately large because the catch per unit of effort is extremely low. Furthermore, in both Canada and the United States, severe restrictions on the size of fish and daily quota have been imposed in recent years. As a result, with some exceptions, the annual sport catch of coho salmon amounts to only a small fraction, roughly one-tenth, of the total annual yield to the two kinds of fisheries.

The heaviest sport fishing for coho salmon takes place in the State of Washington and British Columbia; much smaller numbers are caught in Oregon, California and Alaska. In British Columbia, the average annual sport catch of coho salmon in recent years has been in the order of 200,000 and in Washington, Oregon and California combined it has amounted to almost 350,000 (Table 8). For North America as a whole, therefore, some 600,000 coho salmon are taken annually in the ocean sport fisheries. A significant but unknown fraction of these are immature fish.

Combining the commercial and sport catches of coho salmon in North America provides an average yield on this continent in recent years of 6.4 million fish (using the period 1954-1961 for the commercial catch average, comparable to the period used for the Asian estimate).

In summary then, and using rounded figures, the

TABLE 8. Estimated sport catches of coho salmon in British Columbia during 1953-1961¹⁾, and in the States of Washington, Oregon and California combined during 1952-1958²⁾, in thousands of fish.

Year	British Columbia	Washington, Oregon and California
1952	—	276
1953	130	228
1954	134	284
1955	185	318
1956	198	479
1957	251	564
1958	262	262
1959	243	—
1960	238	—
1961	157	—
Average	200	344

¹⁾ From *Statistics on Salmon Sport Fishing in Tidal Waters of British Columbia*, published annually by the Department of Fisheries of Canada, Pacific Area.

²⁾ Figures for Washington from the Pacific Marine Fisheries Commission as obtained from annual reports of the Washington State Department of Fisheries. Figures for Oregon and California from Wendler (1960).

ratio of recent average annual catches of coho salmon in Asia and North America has been in the order of five to seven millions.

TIME OF ARRIVAL IN COASTAL WATERS

In addition to such influences as oceanic conditions and "established" migratory behaviour patterns, seasonal variations in the high seas distribution of

maturing Pacific salmon must surely be related in a considerable degree to the normal or usual periods of their spawning. Because of this, it is necessary to know the times at which salmon return to coastal waters in order to interpret their occurrence at earlier periods in more distant places. This is particularly pertinent in the event that at some time they intermingle with stocks from the opposite continent.

The period of return of coho salmon to regions of the North American coast can be determined in an approximate manner from available fishery statistics, by observing the times at which various percentiles of the total catch are attained. Obviously, the method cannot achieve complete accuracy, since the commencement, duration and intensity of fishing are subject to regulatory measures which prevent a fully uniform coverage of the runs. In the case of the Asian coho the same approach cannot be made, because the available fishery statistics are not presented on a time basis. Fortunately, some idea of the time of return of Asia coho salmon can be gained from statements made in the U.S.S.R. literature and from the evidence that is inferred by the occurrence of coho salmon in the Japanese mothership fishery.

Referring to runs of some 30 years ago, Gribov (1948) describes the time of return of coho salmon to coastal waters on the east and west coasts of Kamchatka and along the Okhotsk coast on the basis of early and late sightings and their occurrence in the local coastal fisheries. He concluded that, in general, coho salmon migrate at about the same time in the southern and in the extreme northern parts of their range. On both Kamchatkan coasts and along the Okhotsk coast, the main runs occur during the last 20 days of August. Early fish may appear from roughly mid-July and late fish were present into October or even later.

For more recent years, statements by Semko (1954) are in general agreement with the following times given by Moiseev (1955): Okhotsk-Tauisk and West Kamchatka—from the beginning to the middle of August to the middle or end of September; Avacha Bay—from mid-August to October; Kamchatka Gulf—from mid-July to mid-September or October; Rivers of the Komandorski Islands—mid-August; Anadyr Gulf—from the first to the end of September.

Runs to several streams in Hokkaido extend from late September to early October, according to Sano (1959).

As described in more detail later in this report, the catches of coho salmon in the Japanese mothership

fishery increase sharply during late July and August, when the fleet is off the southeast coast of Kamchatka. Tagging results have shown that from this general area the coho proceed to both coasts of the Kamchatka Peninsula and to the Okhotsk coast.

The times of arrival of coho salmon in the outside coastal waters of North America can be determined approximately, in the manner described, from the statistics of the troll fisheries which operate in those waters. Tables 9 to 11 indicate the dates during recent years when various percentiles of the total catch had been reached in southeast Alaska, British Columbia and the State of Washington. It is realized that along the North American coast, numbers of coho salmon probably spend much or all of their ocean residence in coastal waters and do not necessarily migrate far offshore. However, the seasonal build-up in the coastal troll catches and the results of exploratory fishing and tagging in the Gulf (particularly those of the Canadian longlining expedition in 1962) indicate a definite movement into inshore waters from the high seas. Speaking generally then, coho salmon first arrive in appreciable numbers in these coastal waters during early July and the runs extend into late August or early September. Peak catches in the troll fisheries vary between areas and years, but to what extent these variations reflect differences in times of arrival rather than differences due to such factors as availability and fishing effort cannot be

TABLE 9. Dates of attainment, by week-end, of percentiles of total troll catches of coho in outside waters of southeast Alaska, 1957-1959¹⁾.

Year	25%	50%	75%	95%
<i>Area 121²⁾</i>				
1957	July 27	Aug. 3	Aug. 10	Aug. 24
1958	Aug. 2	Aug. 9	Aug. 16	Sept. 6
1959	July 25	Aug. 1	Aug. 15	Aug. 29
Average	July 28	Aug. 4	Aug. 14	Aug. 30
<i>Area 164³⁾</i>				
1957	July 20	Aug. 3	Aug. 10	Aug. 31
1958	July 19	July 26	Aug. 16	Sept. 6
1959	July 11	July 25	Aug. 8	Sept. 12
Average	July 17	July 28	Aug. 11	Sept. 6
<i>Area 173⁴⁾</i>				
1957	July 13	Aug. 3	Aug. 24	Sept. 14
1958	July 19	July 19	Aug. 9	Aug. 23
1959	July 18	Aug. 1	Aug. 29	Sept. 5
Average	July 17	July 28	Aug. 21	Sept. 4

¹⁾ Data provided by United States Fish and Wildlife Service.

²⁾ From north tip of Noyes Island south to Cape Muzon.

³⁾ From just north of Yakobi Island south to Cape Ommaney.

⁴⁾ From Cape Fairweather south to just north of Yakobi Island.

TABLE 10. Dates of attainment of percentile catches of coho salmon by trollers in Statistical Areas 1, 23 and 26, British Columbia, by week-end, 1956-1960¹⁾.

Year	10%	25%	50%	75%	95%	Begin	End
<i>Area 1²⁾</i>							
1956	July 7	July 14	July 28	Aug. 11	Sept. 1	June 2	Sept. 29
1957	July 6	July 6	July 13	Aug. 3	Aug. 31	June 15	Oct. 5
1958	July 5	July 19	July 26	Aug. 16	Aug. 30	June 14	Oct. 4
1959	July 4	July 11	July 25	Aug. 1	Aug. 22	June 20	Sept. 26
1960	July 2	July 9	July 23	Aug. 6	Sept. 3	June 18	Oct. 1
Average	July 5	July 12	July 23	Aug. 7	Aug. 30		
<i>Area 23³⁾</i>							
1956	June 30	Aug. 4	Aug. 25	Sept. 1	Sept. 22	June 16	Nov. 30
1957	June 22	July 6	July 27	Aug. 17	Sept. 7	June 15	Nov. 30
1958	July 5	July 12	Aug. 9	Aug. 23	Sept. 13	June 21	Nov. 30
1959	June 20	June 27	July 11	Aug. 15	Sept. 19	June 20	Nov. 30
1960	June 25	July 2	July 23	Aug. 6	Sept. 17	June 18	Nov. 30
Average	June 26	July 15	July 31	Aug. 19	Sept. 16		
<i>Area 26⁴⁾</i>							
1956	June 30	July 7	July 21	Aug. 11	Sept. 1	June 16	Oct. 20
1957	June 22	June 29	July 13	Aug. 3	Aug. 31	June 15	Oct. 19
1958	July 19	Aug. 2	Aug. 9	Aug. 9	Sept. 6	June 14	Oct. 18
1959	June 20	June 27	July 18	Aug. 22	Sept. 12	June 20	Oct. 31
1960	July 2	July 16	July 23	Aug. 6	Aug. 27	June 18	Oct. 22
Average	July 1	July 9	July 23	Aug. 10	Sept. 3		

¹⁾ Data used are from *British Columbia Catch Statistics*, 1956 to 1960, Department of Fisheries of Canada.

²⁾ Area 1 is Dixon Entrance off the north coast of the Queen Charlotte Islands, and seaward.

³⁾ Statistical Area 23 is off Barkley Sound, west coast of Vancouver Island.

⁴⁾ Statistical Area 26 is towards the northern end of the west coast of Vancouver Island.

TABLE 11. Dates of attainment of percentiles of total coho catches in the State of Washington, 1956-1959¹⁾.

Year	25%	50%	75%	95%
<i>Pacific Ocean Area</i>				
1956	July 28	Aug. 18	Sept. 8	Sept. 29
1957	July 14	Aug. 4	Aug. 25	Sept. 22
1958	July 26	Aug. 16	Aug. 30	Sept. 27
1959	July 18	Aug. 8	Aug. 29	Oct. 3
Average	July 22	Aug. 12	Aug. 31	Sept. 27
<i>Inside Area</i>				
1956	Sept. 22	Oct. 6	Oct. 20	Nov. 10
1957	Sept. 1	Sept. 15	Oct. 6	Nov. 10
1958	Sept. 13	Sept. 27	Oct. 11	Nov. 8
1959	Aug. 29	Sept. 26	Oct. 17	Nov. 7
Average	Sept. 9	Sept. 26	Oct. 14	Nov. 9

¹⁾ Dates were determined from data given in INPFC Statistical Yearbooks.

determined. The attainment dates for the 50 percentiles are rather similar for southeast Alaska and northern British Columbia. The data suggest that farther south the runs tend to build up somewhat later and appreciably so in waters off the coast of Washington.

It is evident that the time of return of coho salmon to coastal waters from the high seas is similar in Asia and North America. In the main, it occurs on both continents during late July and August.

THE OCEAN DISTRIBUTION OF COHO SALMON

Considerable new knowledge of the distribution of coho salmon in the North Pacific Ocean and Bering Sea has been gained in recent years through the operations of the Japanese high seas fisheries and the investigations of United States, Japanese and Canadian tagging and research gillnet vessels. Manzer *et al.* (MS 1963) present and discuss this information in detail and the tables and figures pertinent to coho salmon that are contained in their report should be consulted in conjunction with the following briefer description of the ocean occurrences of coho salmon.

In northern latitudes, maturing coho salmon have been taken intermittently across the width of the Pacific Ocean, in the Okhotsk Sea and at widely-dispersed points in the Bering Sea where fishing has been attempted. During the course of INPFC fishing

operations on the high seas (that is, beyond coastal waters), coho salmon have been caught as far south as 45°N latitude in the eastern half of the North Pacific and at 42°30'N latitude in the western half. They are also known to occur even farther south off North America, in the region of the United States troll fishery that operates on occasion at considerable distances from the southern California coast, and they have also been recorded at sea off the Coronado Islands, Mexico (Briggs, 1953). Concentrations of coho salmon appear in certain ocean areas and the locations of these concentrations change seasonally as the fish approach the coastal waters of the two continents.

Until very recently little was known regarding the dispersal of the immature coho after they left the coast, and only a few had been captured offshore, in the Okhotsk Sea and in the Gulf of Alaska. In 1961, United States tagging vessels caught more than 1,000 juvenile 0-ocean age coho in the Gulf of Alaska. Some of these fish were taken from as early as in June, through July and August to as late as in September. Most captures were made within a few miles of the coast, but some were taken nearly 100 miles offshore.

IN THE NORTH PACIFIC AND BERING SEA

During the months of May and June, only a very

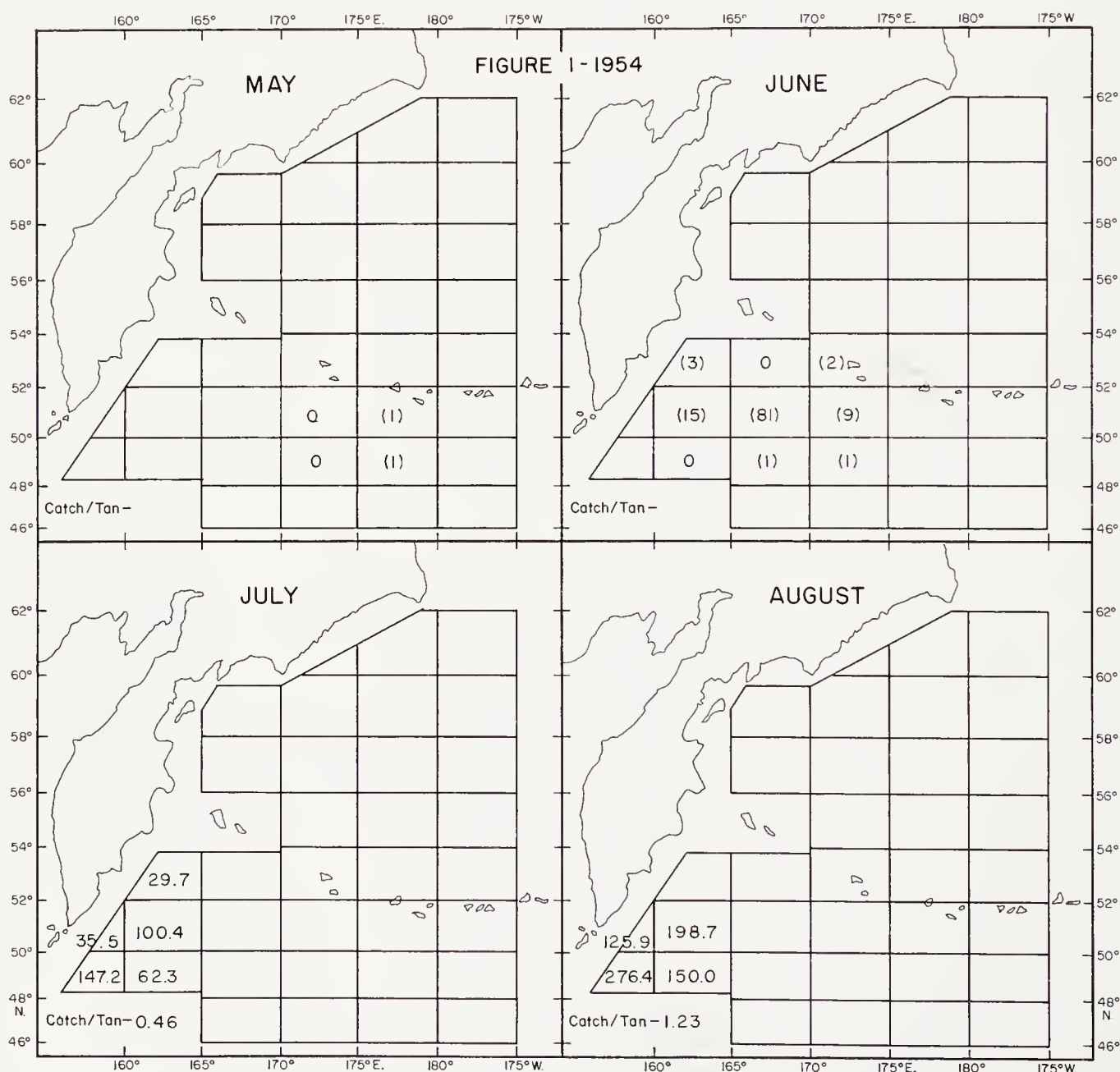
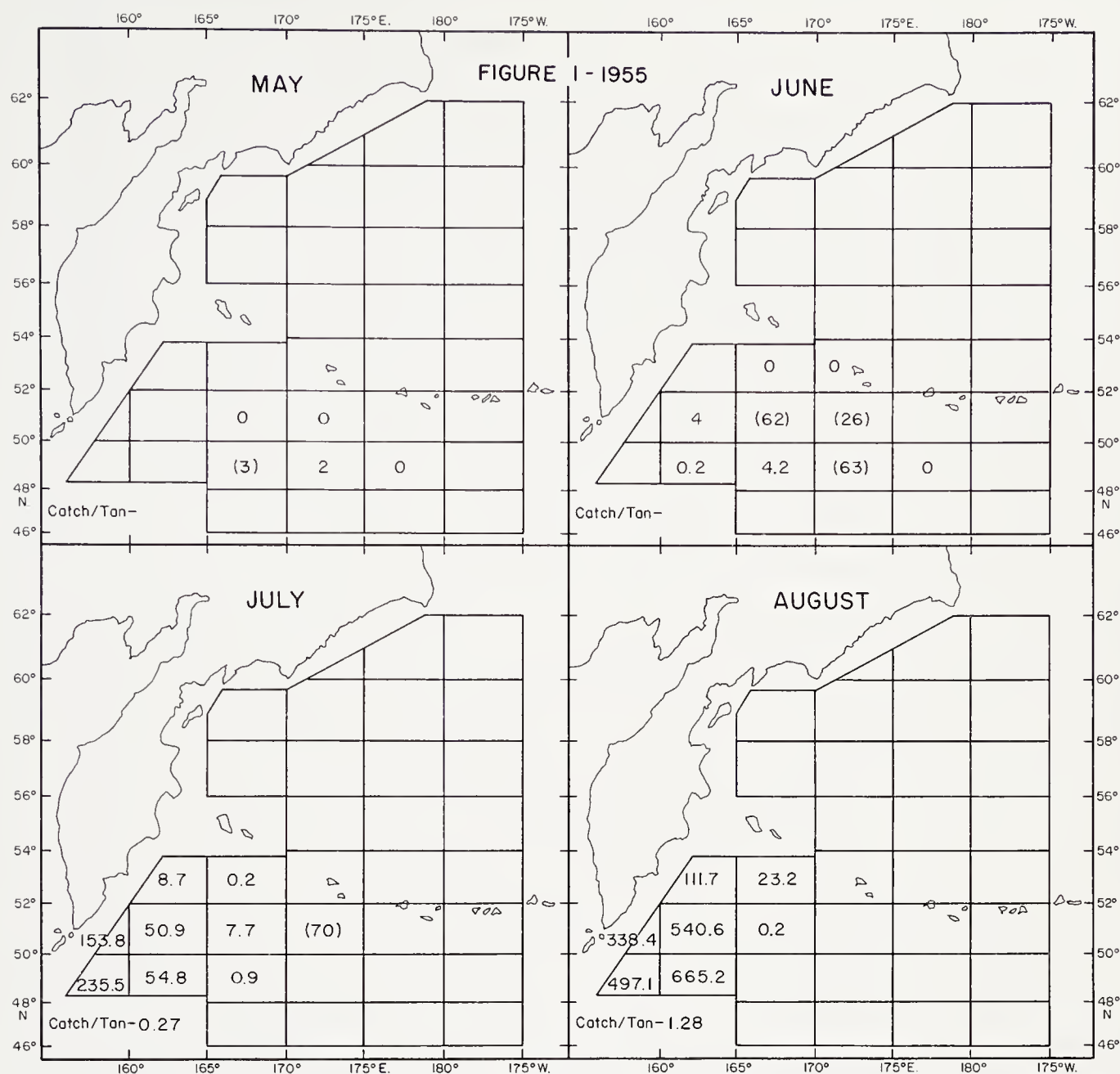


FIGURE 1. Monthly catches of coho salmon in the Japanese mothership fishery, 1954–1961 (eight drawings). (All figures in brackets are for numbers of fish; figures not in brackets are for thousands of fish.)

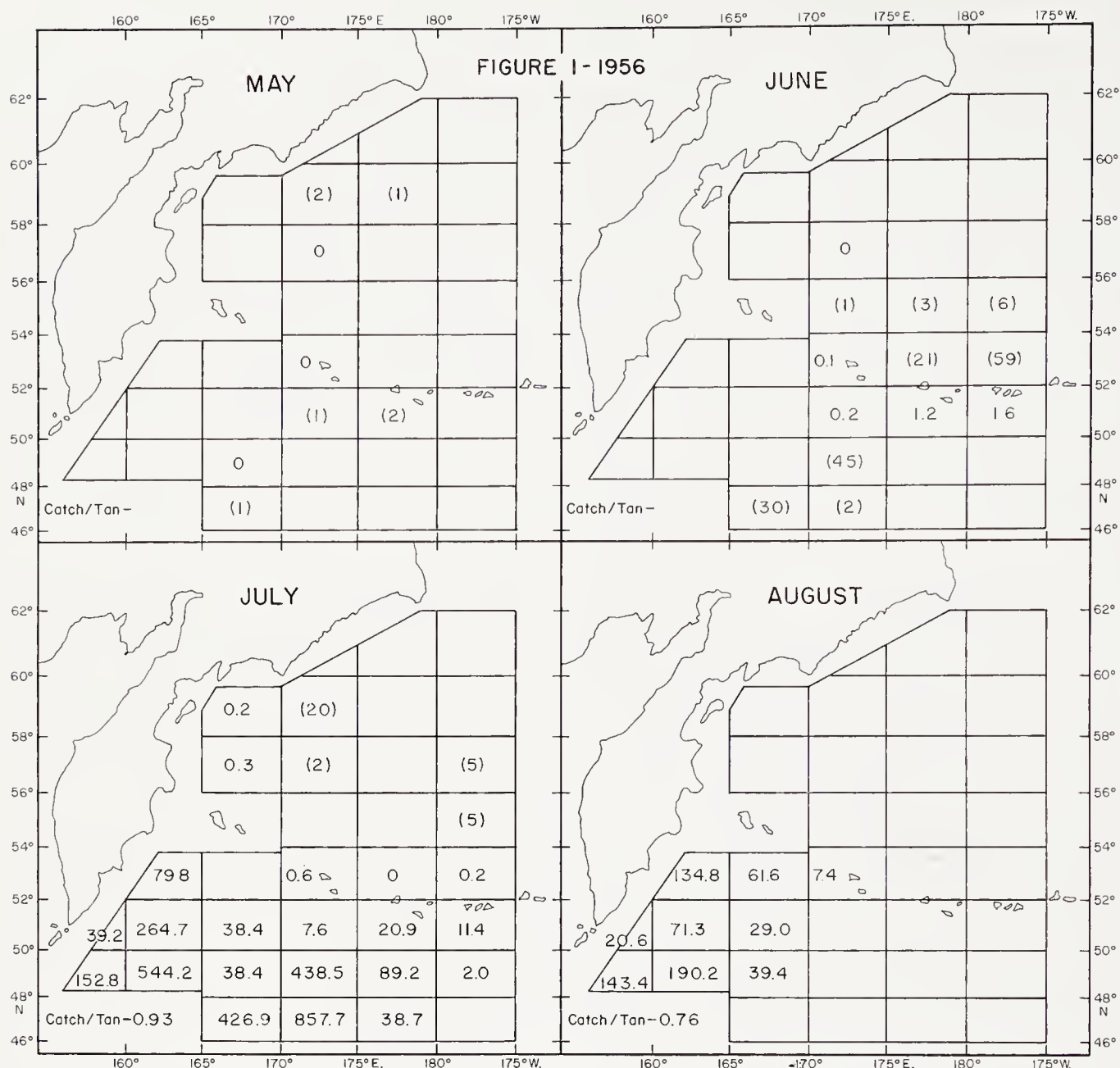


few coho have been taken in the northern North Pacific and Bering Sea to at least as far south as about 40°N latitude (in some areas and in some years), despite considerable fishing by both commercial and research vessels. The coho catches in these months for all years combined have amounted to only a few thousand fish. This indicates that up to this time the main concentrations of coho, which later do appear in these waters, must lie farther to the south. A slight increase in the very small catches of coho off southeast Kamchatka north of 48°N latitude during the latter part of June indicates the beginning of a northward movement into that general area. The low abundance of coho salmon in these waters during these months, as compared with their much greater abundance later in the season, is in marked contrast with the

relatively high abundance of mature sockeye, pink and chum salmon in May and June in the same areas.

In the Aleutian area of the Japanese mothership fishery, the coho catches (Fig. 1) and the catch per unit of effort¹ (see Manzer *et al.*, MS 1963) increase sharply during July and August. Also, in these months, and particularly in August (in those years when the fishery has operated in that month), the coho catches form a much greater fraction of the combined salmon catch than in earlier months (Fig. 2). An indication of the changes in the abundance of coho in western Aleutian waters and off southeast Kamchatka from May to August, and of the actual numbers of fish

¹ Japanese fishing effort is measured in "tans" of gillnet; one tan is approximately 180 feet.



involved in the catches, may be gained from Table 12. From a few thousand fish caught in June, peak catches in the last two months of the fishery have gone as high as 3.1 million in July (1956) and 2.2 million in August (1955), only part, if any, of which month was fished in any year. From a catch per unit of effort averaging considerably less than 0.01 in May and June, values in July and August have been as high as 0.93 (1956) and 1.78 (1958), respectively. During July and August, the mothership fishery shifts westward and concentrates in waters off southeast Kamchatka, principally south of the western Aleutians and the Komandorski Islands (Fig. 1). In general the catches per unit of effort for July, and sometimes for August also, have tended to be greater in the outer

southern and southeastern areas of this region, indicating that the coho approach the Kamchatka Peninsula over a broad front, mainly from the south and southeast.

Farther to the south also, in the region of the Hokkaido landbased driftnet fishery (roughly eastward of the Kuril Islands between 45°N and 48°N latitudes), the coho catches increase sharply during July and August and again indicate a source from the south and southeast (Nakatsu, 1960). Seasonal data on the numbers of coho taken in this fishery cannot be given, since the catches are combined with those of chum, sockeye and chinook salmon in the available statistics.

Catches by research vessels have shown a similar

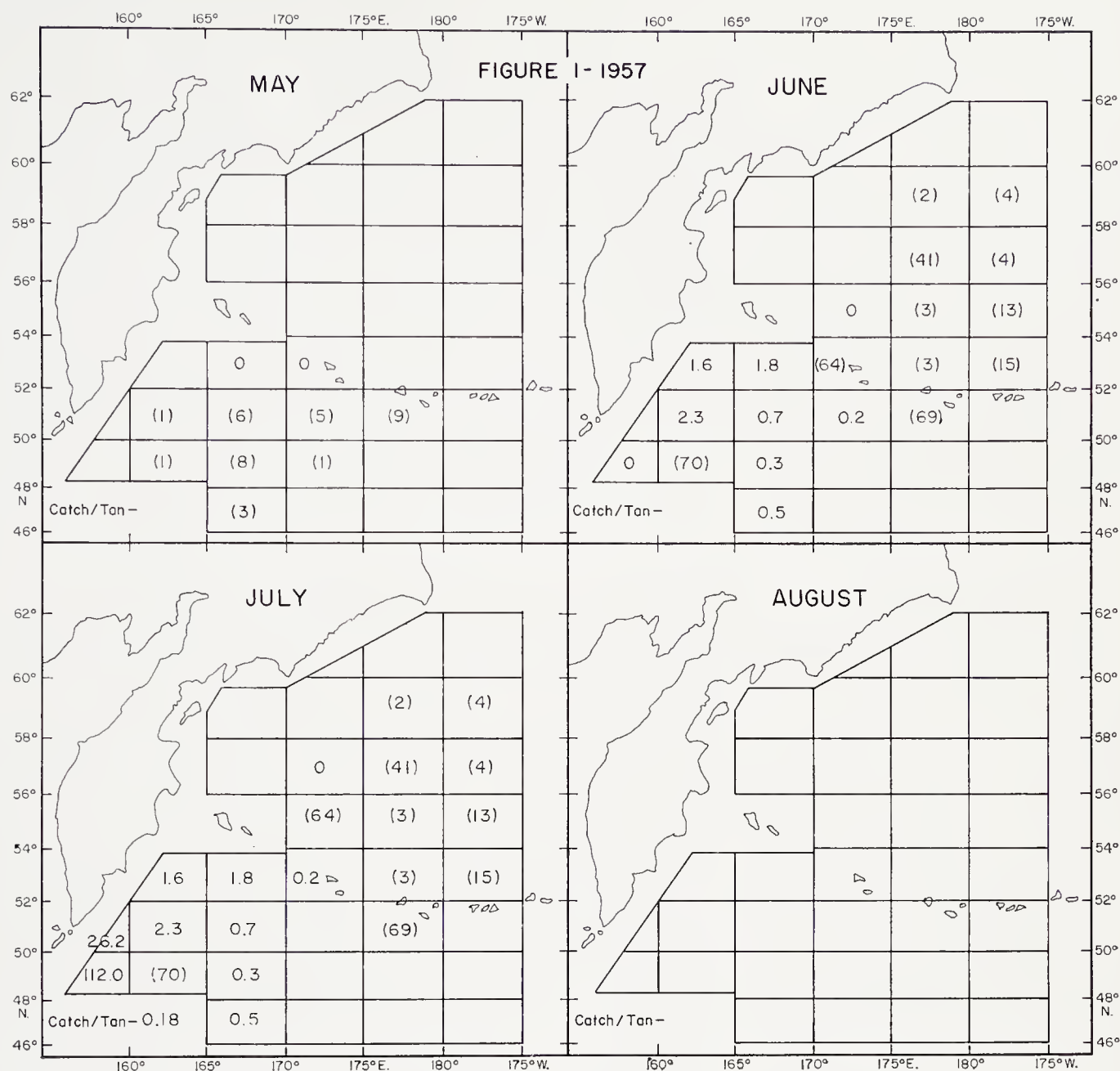


FIGURE 1. Continued.

marked increase in the abundance of coho salmon during July and August in these same general areas. These operations have also indicated the presence of important numbers of coho along the south side of the Aleutian Islands west of 175°W longitude and to the south (Figs. 3 to 7)¹.

¹ With reference to Figures 3 to 7, it should be noted that they are intentionally diagrammatic. Because the three countries used somewhat different kinds and amounts of gear, direct comparisons cannot be made between the catches at stations occupied by different countries. However, the differences in apparent abundance that are discussed in the text are the very great differences that occur between major ocean areas, or the major seasonal changes, that are not accounted for by the relatively small differences between mesh sizes used or in fishing effort. A more detailed comparison of catches is contained in Manzer *et al.*, MS 1963.

In the eastern half of the North Pacific, the observed coho concentrations have been very much smaller than in western waters and very few have been taken south of 50°N latitude. The lack of a high seas commercial fishery in the eastern half of the North Pacific limits our knowledge of the ocean occurrence of coho in those waters to the results of the research vessel operations (Figs. 3 to 7). From these, it is apparent that in the Gulf of Alaska coho salmon have not been encountered in such large concentrations as occur off southeast Kamchatka. Rather, they are probably more widely dispersed over the Gulf and large concentrations probably do not occur until they are within coastal waters in areas where they are exploited by the coastal fisheries.

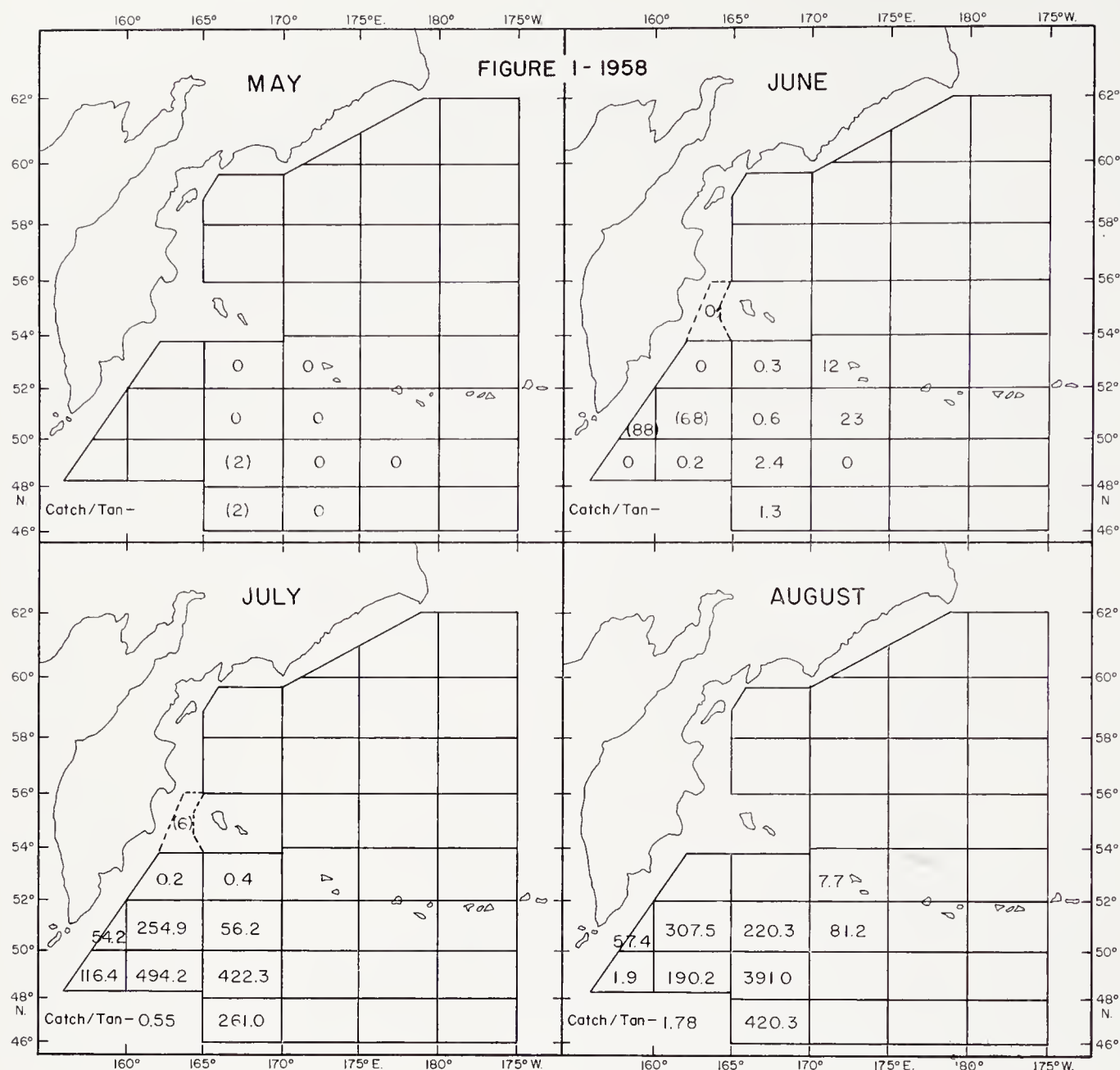


FIGURE 1. Continued.

The results of the Canadian tagging operations in 1962 give some additional information on the distribution and movements of coho salmon in the Gulf of Alaska.

Figure 8 shows the weighted catches (i.e., catch weighted to 20 skates of gear) of coho salmon during six periods from April 9 to July 26, 1962. Early in the season, small numbers of coho were taken only in the southeastern area of the Gulf; none was taken in either more westerly or more northerly waters. As the season progressed, the coho appeared to advance, mainly in a northwesterly direction, towards the center of the Gulf where, during the latter half of of June, they formed a concentration in the general area of 52°N latitude, 140–145°W longitude. By the

end of July, the coho had dispersed from the more central region of the Gulf to inshore waters, at which time they were being taken in numbers in the various coastal fisheries.

In the Bering Sea, larger catches of coho are made in the area of the mothership fishery during July and August than earlier. Some of these fish undoubtedly enter the Bering Sea from the concentrations that occur along the Aleutian Chain from 175°W longitude and westward, while the source of other catches must be the concentrations off southeast Kamchatka. It is difficult to assess their abundance since only a small fraction of the mothership effort during July and August has actually taken place within the Bering Sea. Research vessel catches indicate that they are

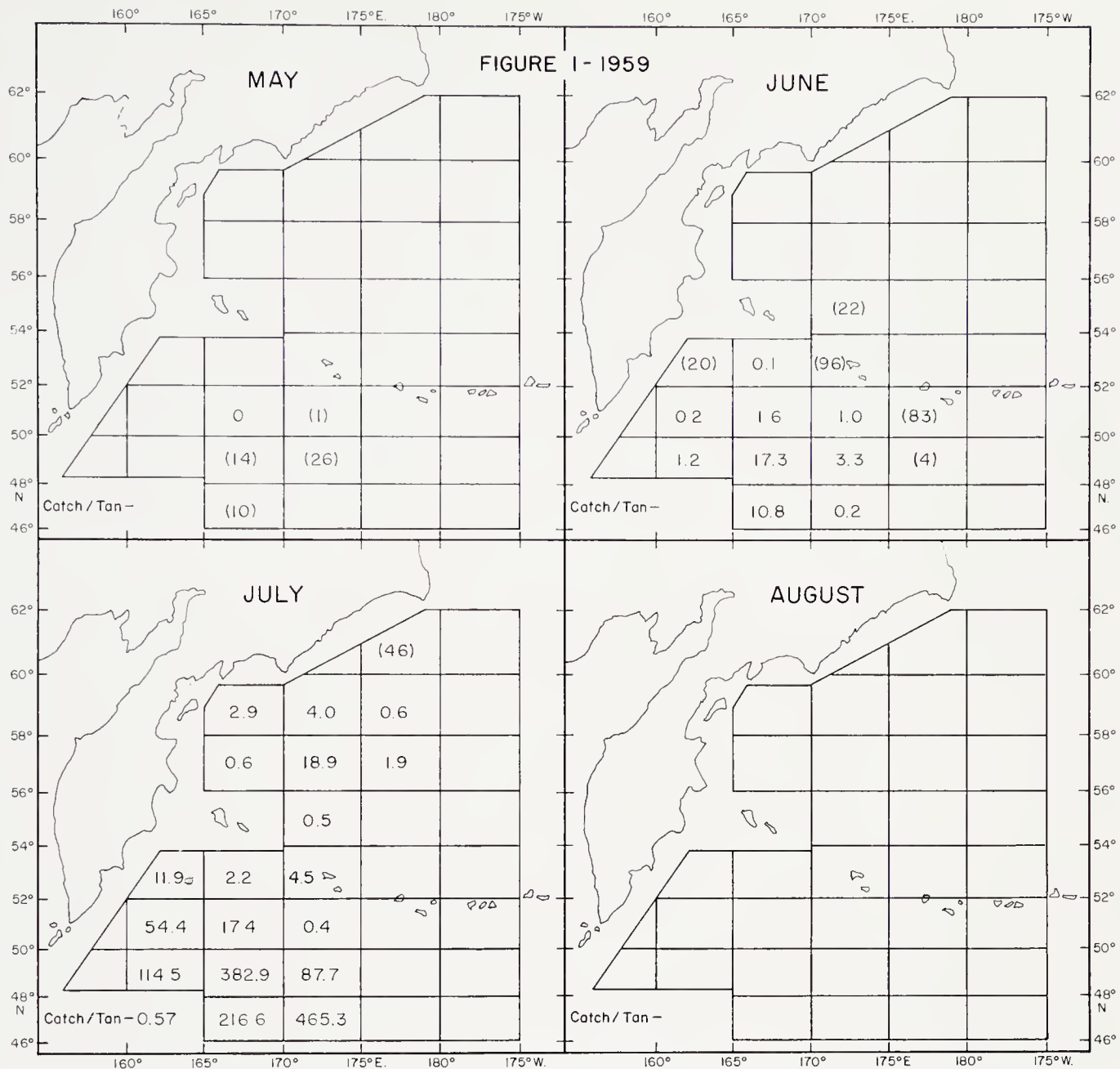


FIGURE 1. Continued.

not numerous and are rather widely dispersed until relatively close to the East Kamchatkan coast.

In the central and eastern Bering Sea, research vessel catches indicate that coho are scarce during the entire season. Small concentrations have been noted close to the Aleutian Islands and, later in the season during August, well to the east near western Alaskan shores. However, fishing effort after June in the Bering Sea east of 180° has not been extensive, so that these conclusions must be considered as tentative.

IN THE OKHOTSK SEA

Japanese motherships have operated in the Okhotsk Sea off the West Kamchatkan coast during 1955 to 1958, inclusive. The latitudinal boundaries of the

waters fished in these years have varied between 49°N and 55°N, but most of the fishing has been done between 50°N and 53°N latitudes. The total coho catch has dropped progressively during this period, from 392,000 to 51,000, in association with reduction of total fishing effort. The catch per tan in both July and August has shown no definite trend during these years (Table 13). Furthermore, in each year the catch per tan has shown an increase from July to August. This indicates that the abundance of maturing coho in the Okhotsk Sea, as off southeast Kamchatka, increases late in the season during late July and August.

Most of the gillnetting effort by Japanese research vessels in the Okhotsk Sea took place in 1962 and the

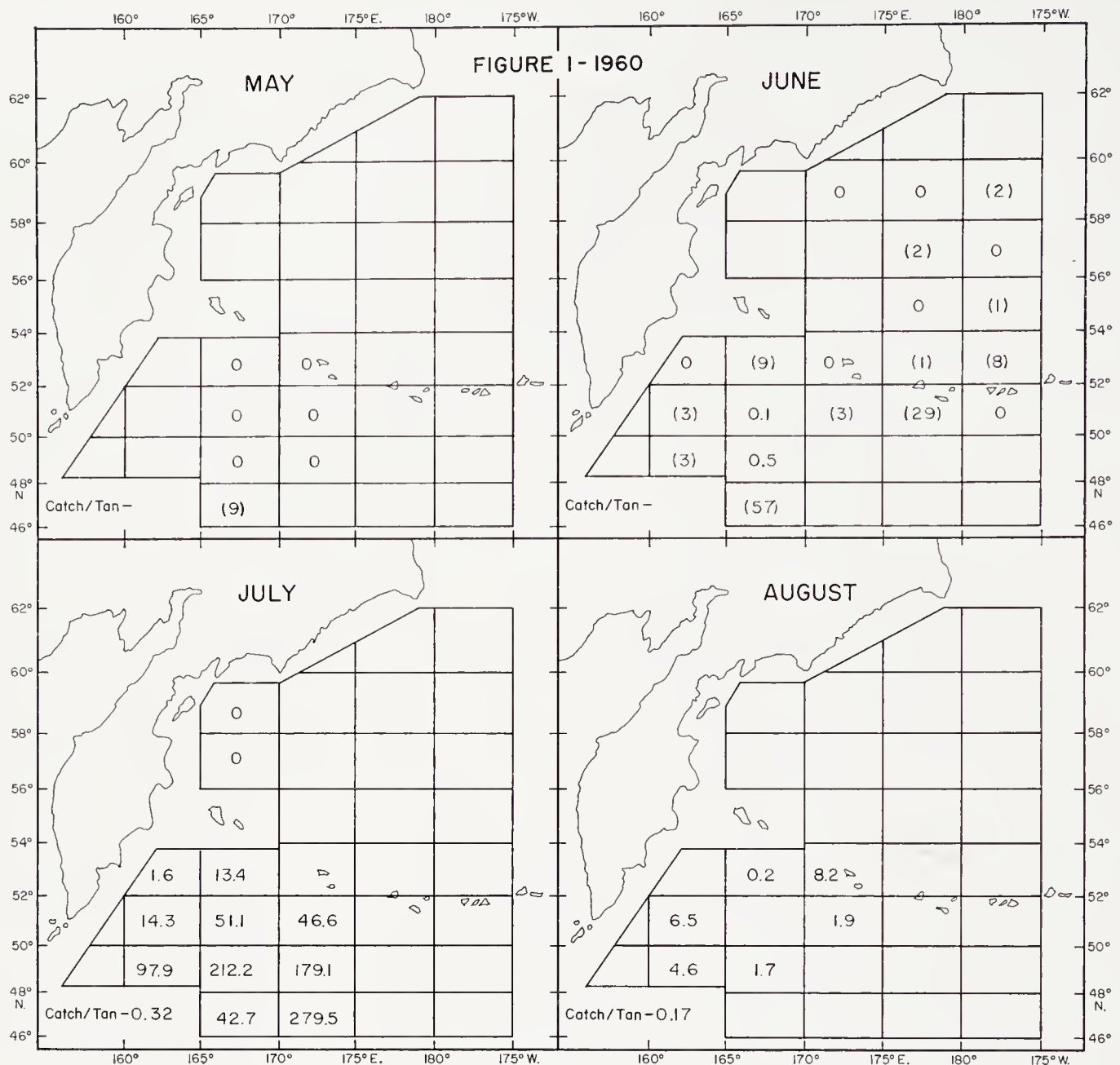


FIGURE 1. Continued.

results for that year also indicate the build-up of coho salmon in those waters during July and August (Figs. 3 to 7). Tagging results, described later in this report, show that the migrations of maturing coho into the Okhotsk Sea occur by way of the Kuril passes, originating off southeast Kamchatka and from points still farther to the south and southeast. The paucity of coho catches in the more southerly waters of the eastern Okhotsk Sea (that is, in the vicinity of the southern Kuril Islands) suggests that most of the migration into the Okhotsk Sea probably takes place through the more northerly passes and Kuril Strait.

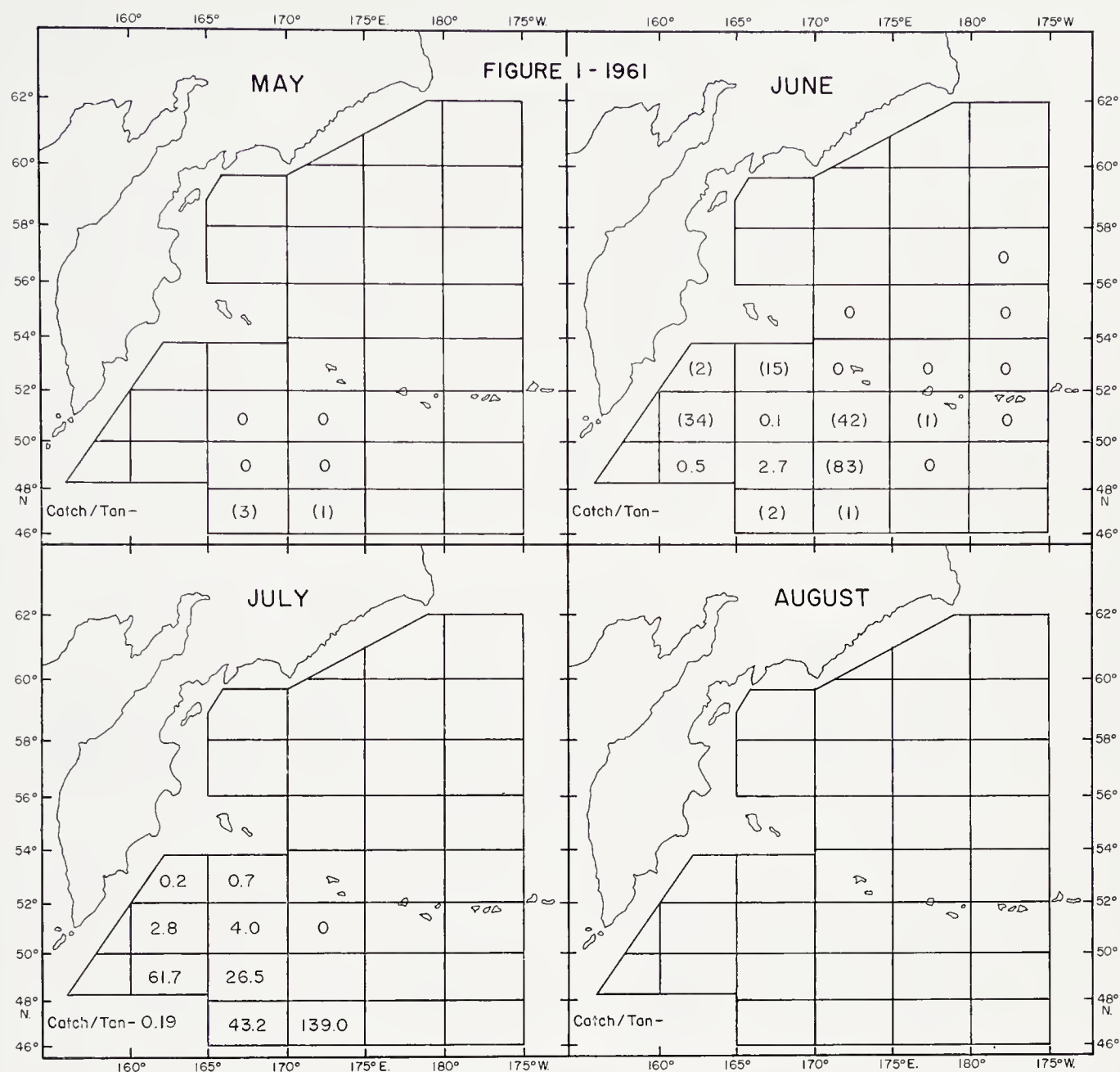
In 1962, most of the coho tagged in the Okhotsk Sea were small, juvenile fish. The majority was captured in August relatively close to the west coast of

Kamchatka, below 55°N latitude.

AGE, LENGTH AND MATURITY

A few data are at present available from the Japanese high seas fisheries and from Canadian research vessel operations on the age, length and maturity of coho salmon taken on the high seas. These are presented in detail in Manzer *et al.* (MS 1963) and are summarized here briefly. (Manzer *et al.* (MS 1963) should also be consulted for the locations of the different regions of the Japanese fisheries.)

In 1959 and 1960, in the western North Pacific and western Bering Sea (Table 14), 3₂, 4₃ and 5₄ coho constituted almost the complete age composition of the coho catches in the Japanese commercial fisheries.



reservation for the time being.

Table 15 summarizes some length data for coho salmon captured in the Japanese fisheries in 1957-1960; they have been extracted from more detailed information contained in appendices to Manzer *et al.* (MS 1963). Consistent differences in the fork lengths of coho in the several fisheries regions are not overly apparent. Where data are appropriate for comparison, males appear to be longer on the average than females early in the season, but not invariably so later. In general, an increase in length for both sexes is evident from June to July and August, a rough approximation of which would be 2 cm from June to August. From the figures for 1959 and 1960, it is apparent that both male and female 4₃ fish are slightly

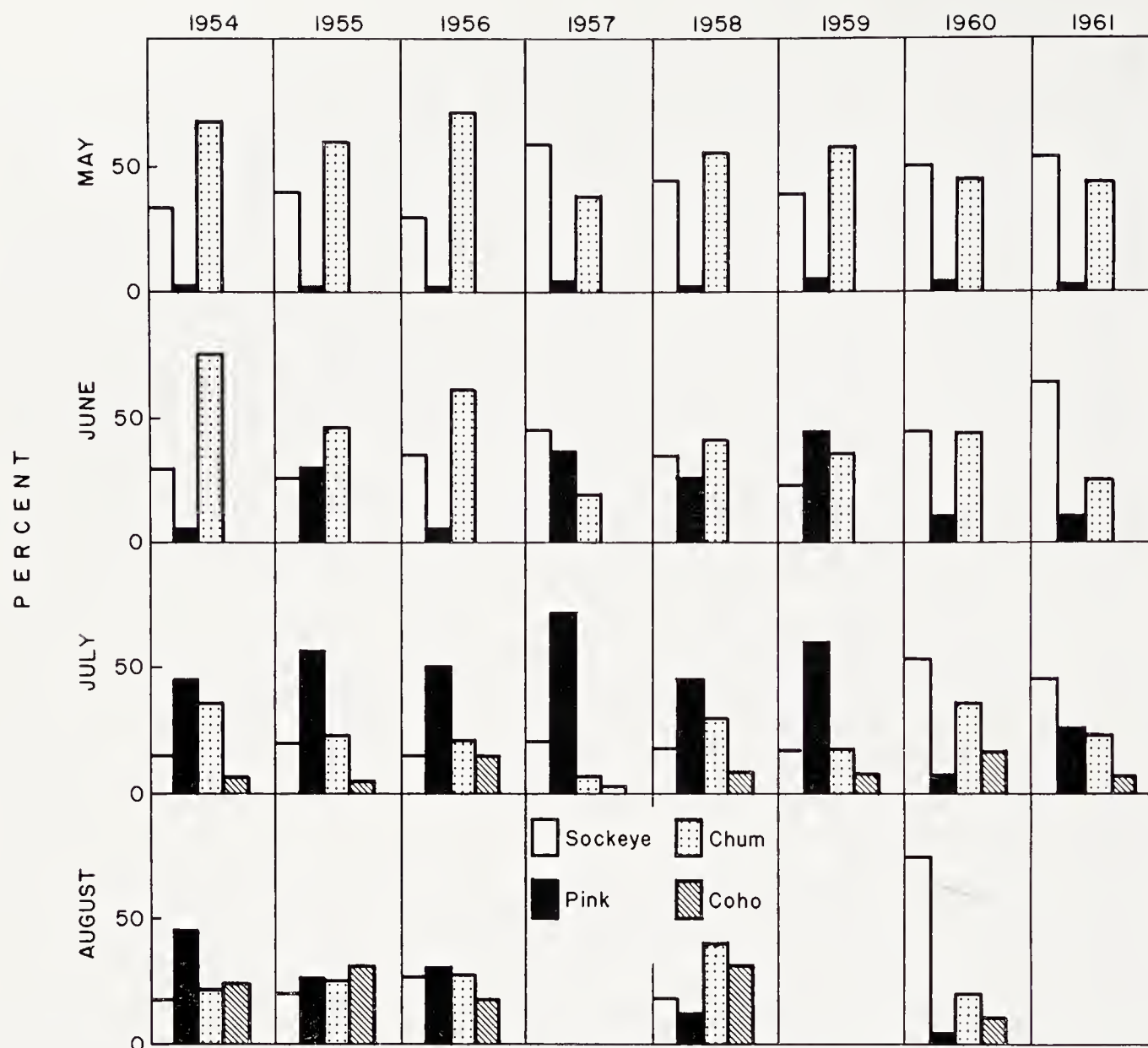


FIGURE 2. Japanese mothership fishery, 1954-1961. The catch of Pacific salmon by species, as a percentage of the total catch of all species, by month (using numbers of fish).

TABLE 12. Coho catches and catch per tan by the Japanese mothership fishery in the Aleutian area, in numbers of fish, 1954-1961¹⁾.

Year	Catch				Catch per tan			
	May	June	July	Aug.	May	June	July	Aug.
1954	2	112	375,008	750,985	Less than 0.01 for all years and both months combined		0.46	1.23
1955	5	4,559	512,481	2,178,420			0.27	1.28
1956	7	3,370	3,051,734	697,611			0.93	0.76
1957	34	7,726	331,863	—			0.18	—
1958	4	5,033	1,659,909	1,677,399			0.55	1.78
1959	51	35,900	1,387,138	—			0.57	—
1960	9	737	938,213	22,994			0.32	0.17
1961	4	3,467	280,585	—			0.04	—

¹⁾ Data from INPFC Statistical Yearbooks. One taneis approximately 180 feet.

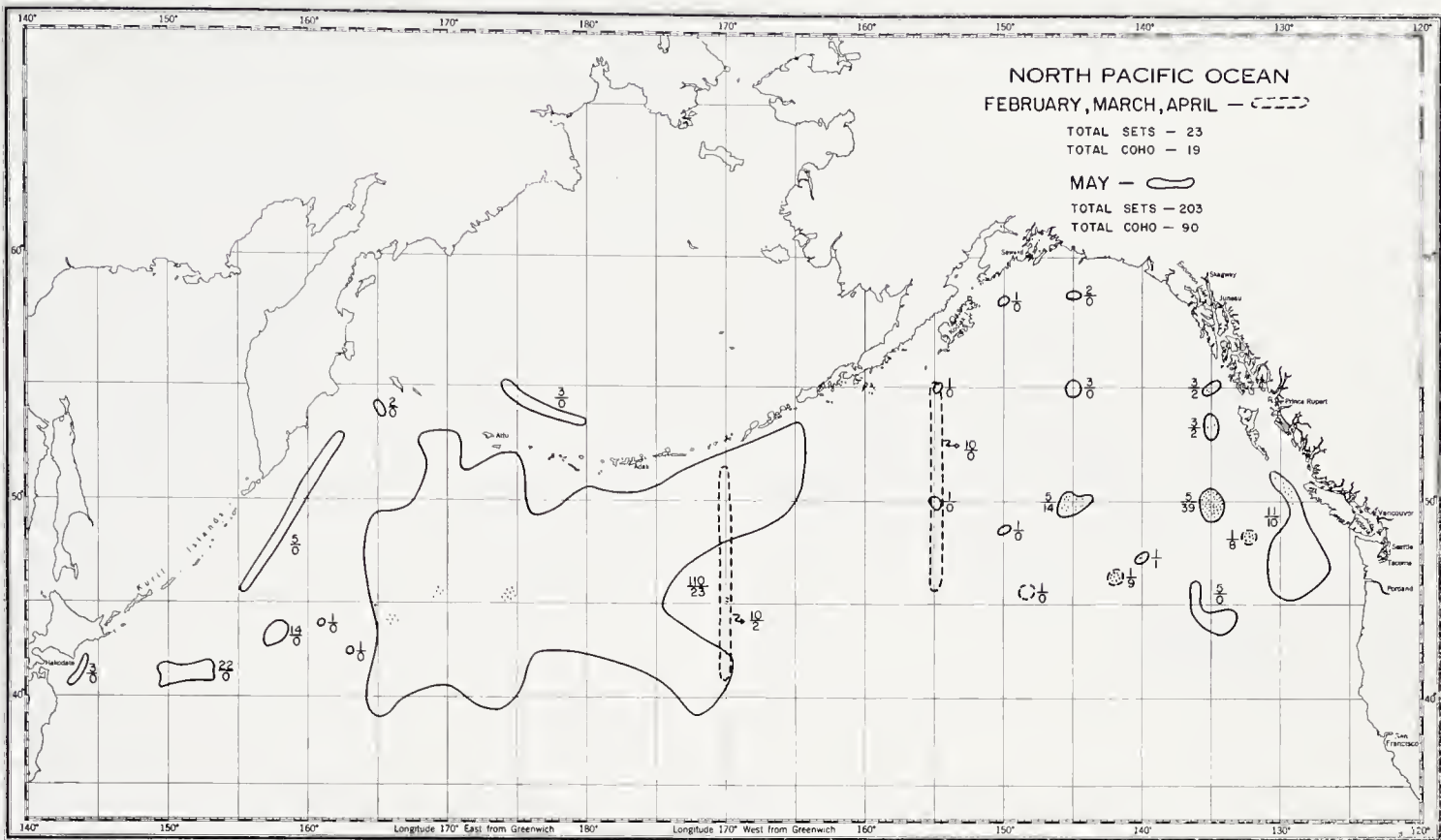


FIGURE 3. Catches of coho salmon by Japanese, United States and Canadian research gillnet vessels for the years 1956-1962 combined, *February, March, April and May*. The areas embracing fishing stations are outlined; the locations of coho catches are shown by stippling. The upper numeral shows number of sets made in an area; the lower numeral shows number of coho salmon caught.

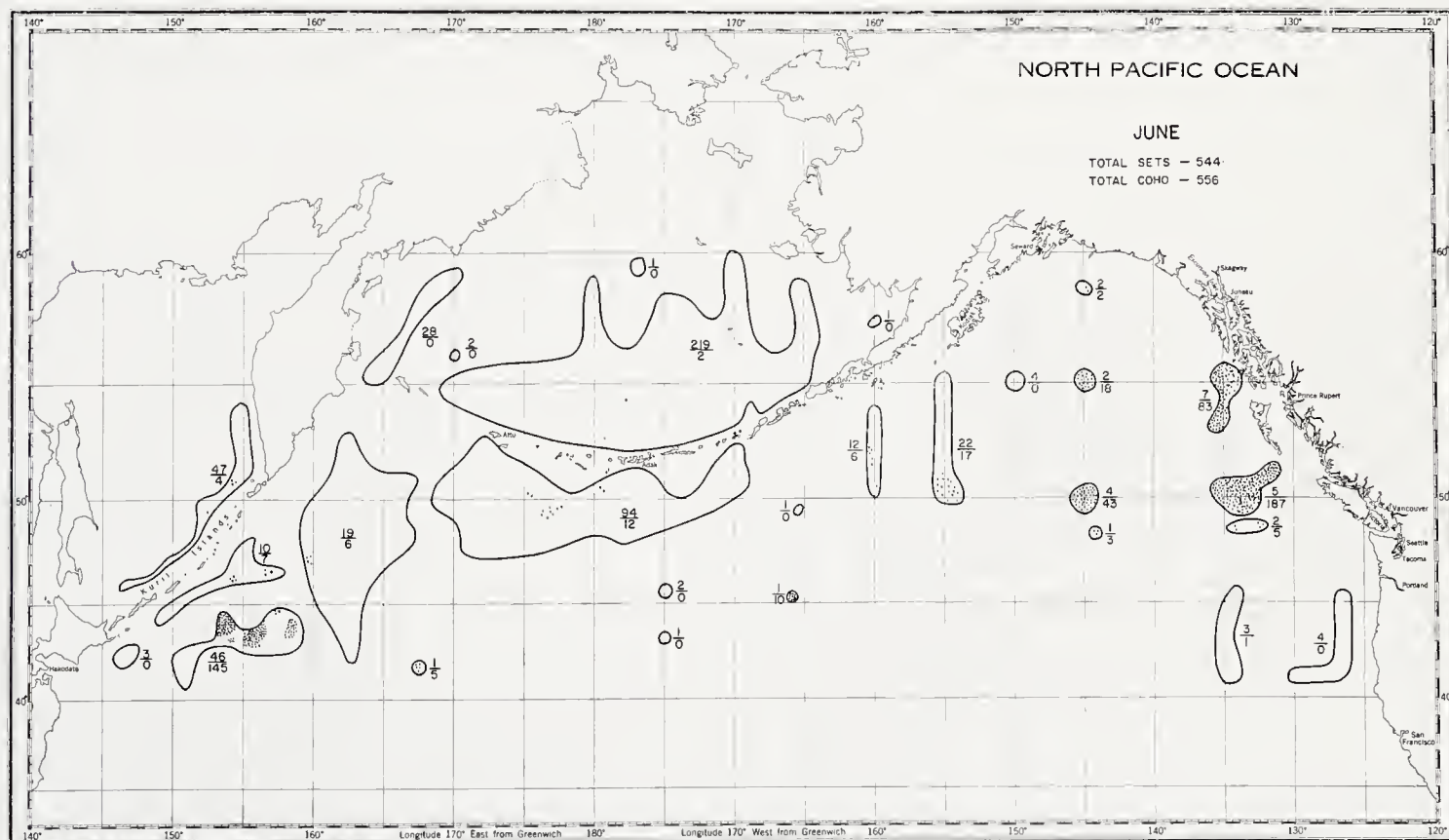


FIGURE 4. Catches of coho salmon by Japanese, United States and Canadian research gillnet vessels for the years 1956-1962 combined, *June*. See Figure 3 caption for legend.

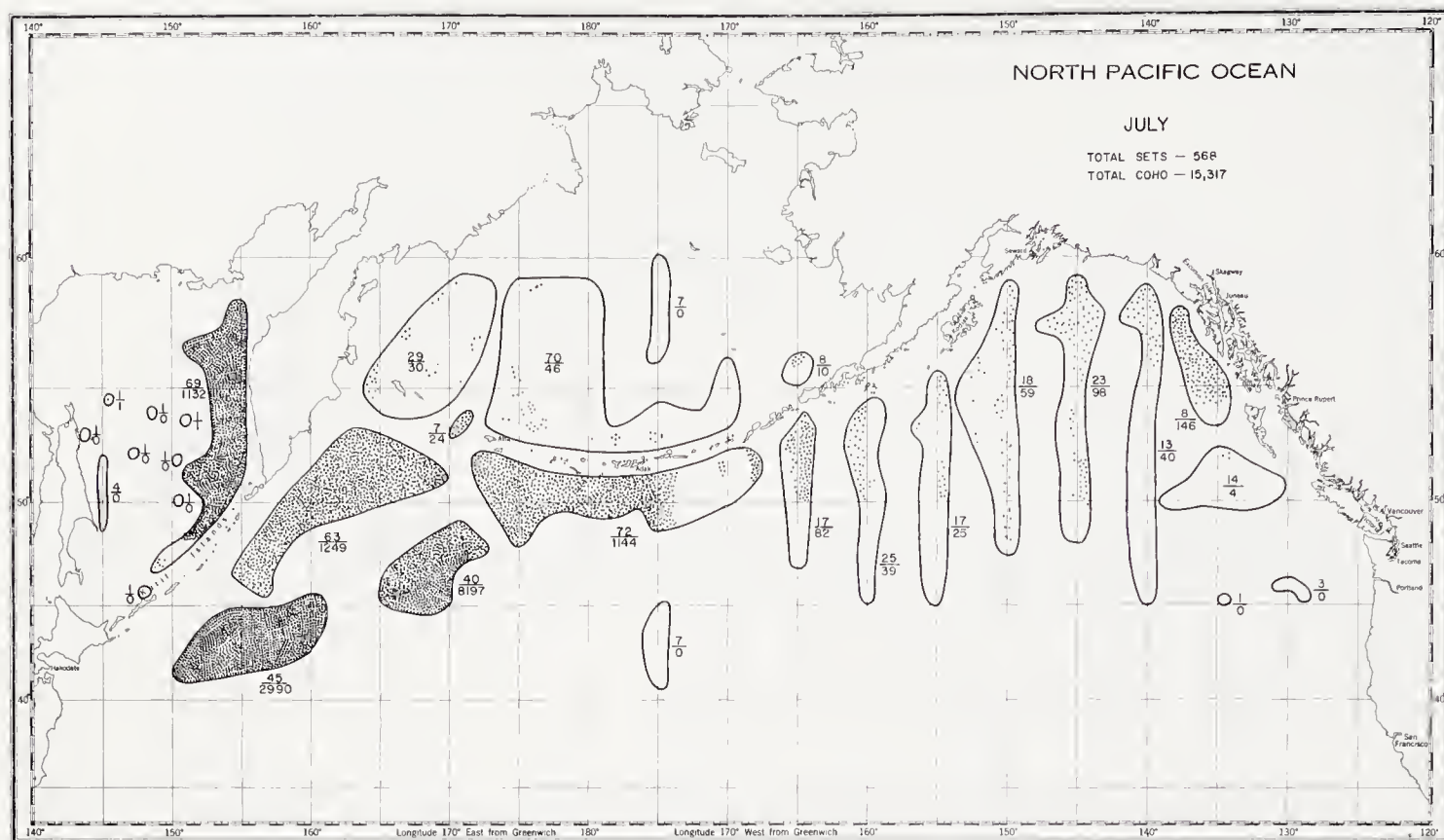


FIGURE 5. Catches of coho salmon by Japanese, United States and Canadian research gillnet vessels for the years 1956-1962 combined, *July*. See Figure 3 caption for legend.

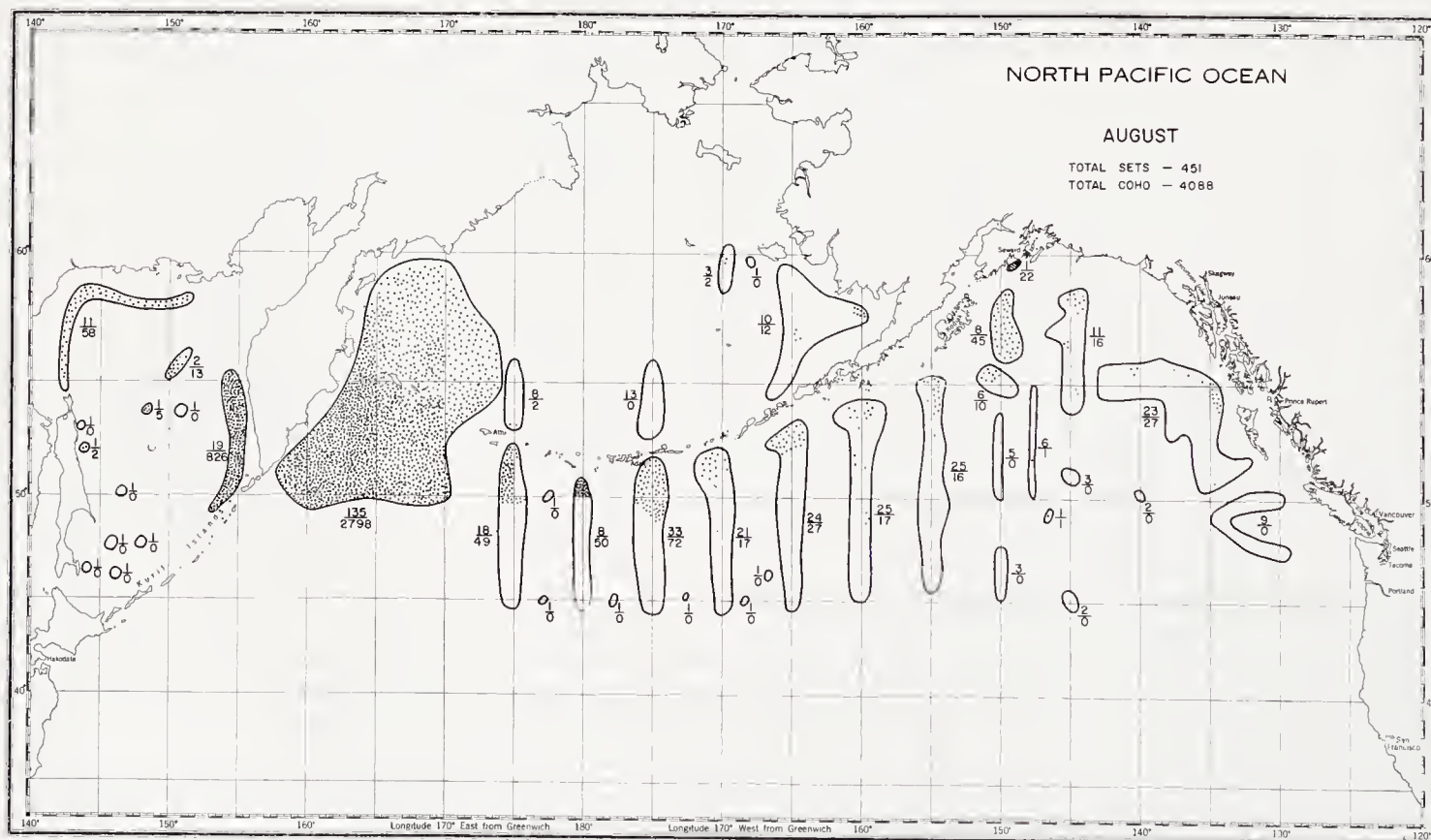


FIGURE 6. Catches of coho salmon by Japanese, United States and Canadian research gillnet vessels for the years 1956-1962 combined, *August*. See Figure 3 caption for legend.

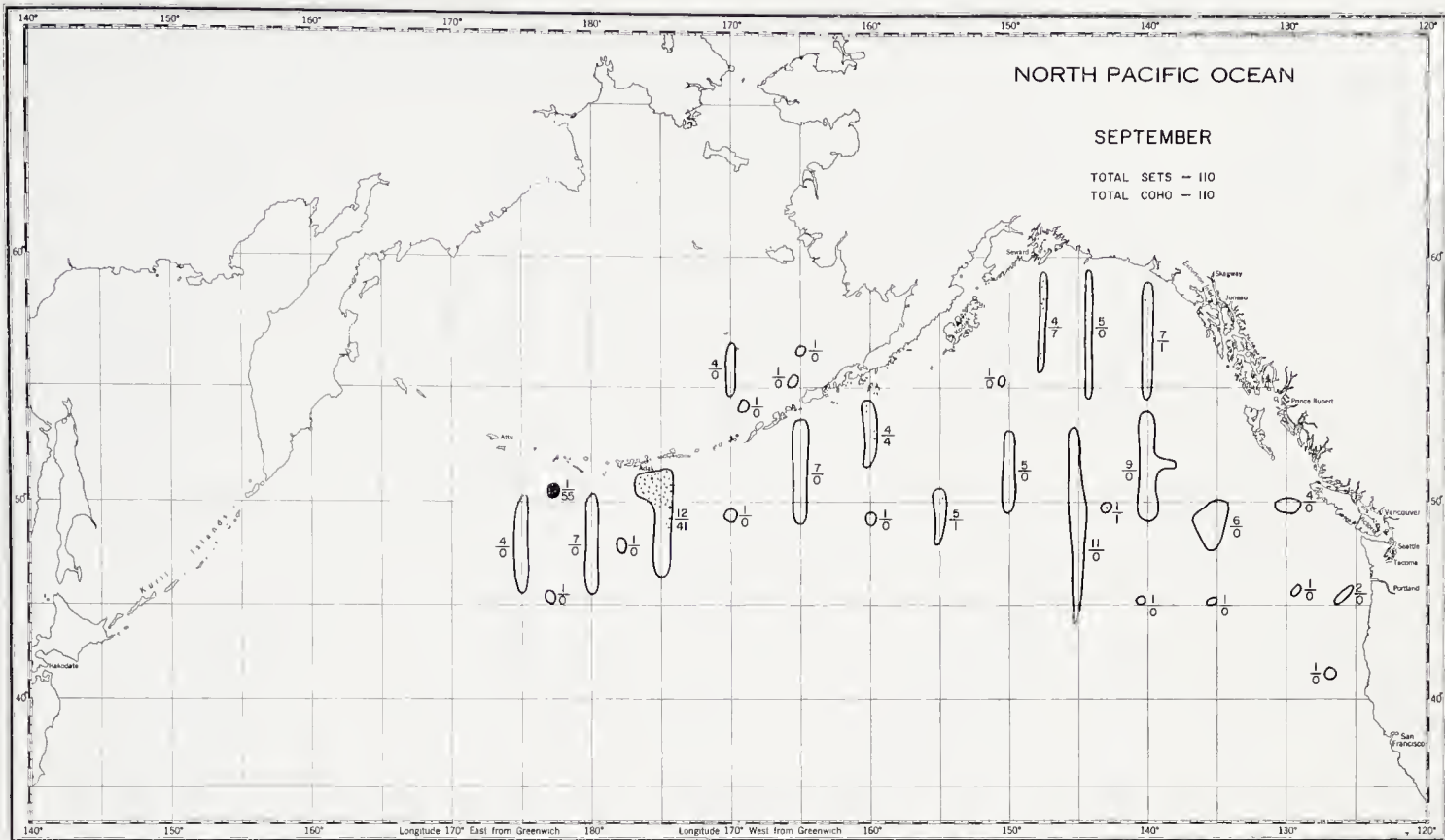


FIGURE 7. Catches of coho salmon by Japanese, United States and Canadian research gillnet vessels for the years 1956-1962 combined, *September*. See Figure 3 caption for legend.

longer than the 3₂ fish at the same time in the same region. The few coho taken in May were almost invariably smaller than those taken in June.

Some indication of the weights of coho salmon taken by the Japanese in these waters in 1960 is contained in Table 16. Definite increases in average weight from May/June to August are evident for both sexes.

Average lengths and weights of coho salmon taken by Canadian research vessels in the Gulf of Alaska in 1957 were as follows:

	May	June	July	August
Number	5	283	30	4
Length (cm)	58.4	56.6	59.4	63.3
Number	5	236	28	4
Weight (lb)	5.0	4.9	5.6	7.1
(kg)	2.3	2.2	2.6	3.2

Extremely few coho salmon remain a second year in the ocean, so that with few or no exceptions those taken in the waters of the Japanese high seas fisheries and by Canadian vessels in the Gulf of Alaska have been maturing fish (for gonad weights of the Canadian catches see Manzer and Neave, 1958; 1959). In the Japanese high seas fisheries, it is evident that the degree of maturity increases during the course of the

season, as is indicated in the summary provided in Table 17.

A few immature coho, in their first ocean year, have been captured by purse seines of United States tagging vessels in the Gulf of Alaska. Lengths at time of tagging of nine of these that were recovered a year later were as given in Table 18.

OCEAN MIGRATIONS

The ocean migrations of maturing Asian and North American coho salmon can best be described here by summarizing the information gained from high seas fishing and from tagging.

Catches by the Japanese high seas fisheries and by research vessels in the western North Pacific indicate that maturing Asian coho move towards the southern tip of the Kamchatka Peninsula over a broad front that probably extends in a southwesterly direction from the central Aleutians to waters off Hokkaido. As has been described, they begin to enter these northerly waters in numbers during late June, reaching peaks of abundance there during late July and August. They presumably enter the Bering Sea through Aleutian passes (since they have been encountered in numbers close to the northern shores of the islands and farther north, at least from about

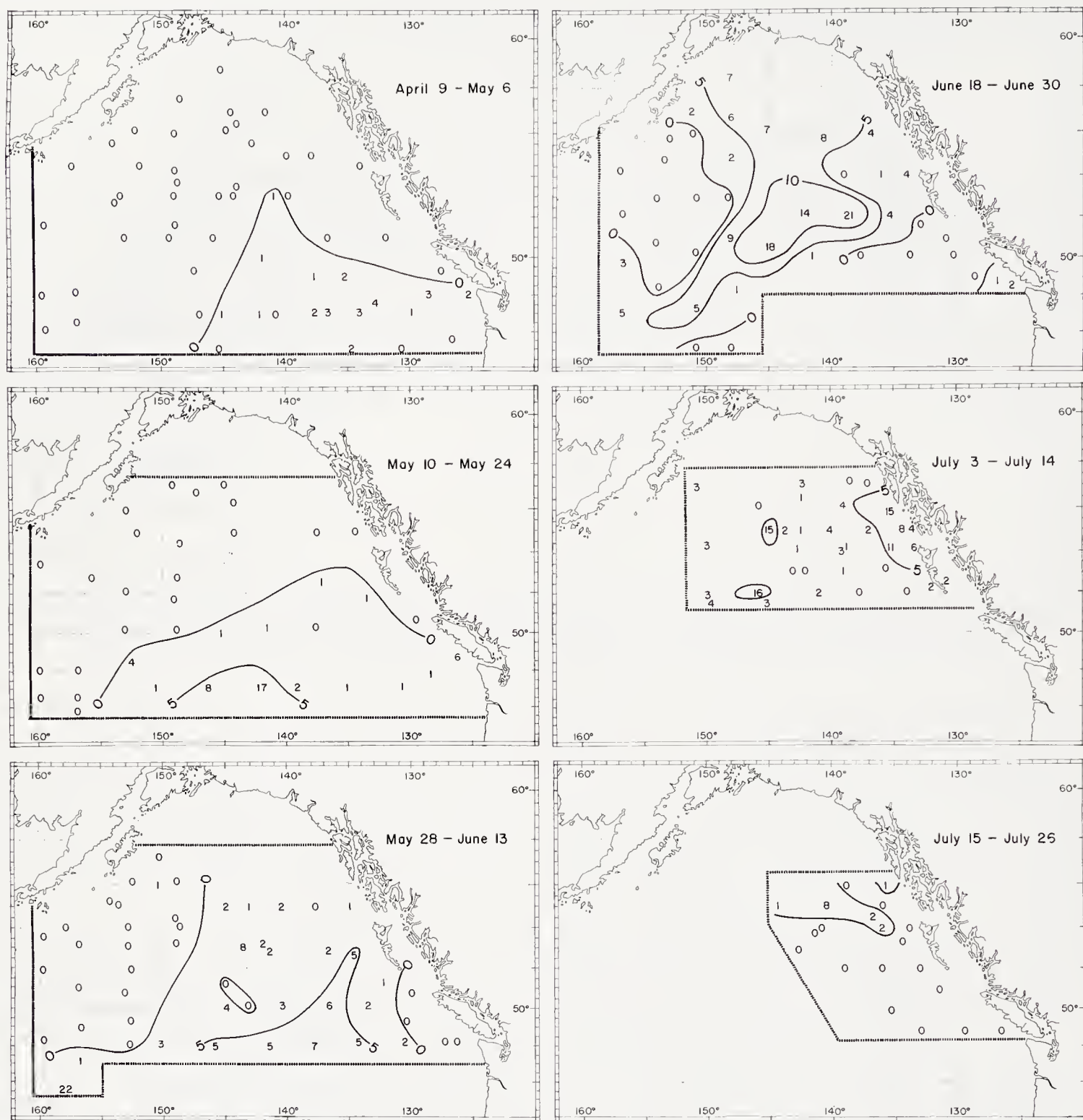


FIGURE 8. Catches of coho salmon by Canadian longline vessels in the Gulf of Alaska in 1962, in numbers of fish weighted to twenty skates of gear, by periods.

175°W longitude westward) and also along the East Kamchatkan coast from among the concentrations off southeast Kamchatka. These concentrations off the southern tip of the Kamchatka Peninsula also provide runs of coho to the west coast of Kamchatka and the Okhotsk Sea coast, as indicated by tagging. The results of gillnetting by Japanese research vessels in the Okhotsk Sea (mainly in 1962) indicate that the

principal movement of the maturing coho off the west coast of Kamchatka is northward rather than over a broad or dispersed front in that sea (Figs. 3-7).

Catches by research vessels in the eastern half of the North Pacific (including the Gulf of Alaska) and the eastern Bering Sea have not been sufficiently large or consistent to provide more than a very general

TABLE 13. Coho salmon catches and effort in the Okhotsk Sea by the Japanese mothership fishery, 1955-1958, in thousands of fish and thousands of tans¹⁾.

	1955		1956		1957		1958	
	1,000's of fish	1,000's of tans	1,000's of fish	1,000's of tans	1,000's of fish	1,000's of tans	1,000's of fish	1,000's of tans
June	1	268	—	111	+	265	+	162
July	43	326	105	332	102	247	24	176
Catch per tan	0.132		0.316		0.413		0.136	
August	332	168	13	35	No fishery		27	55
Catch per tan	1.976		0.371				0.491	
Total	376	762	118	478	102	512	51	393

¹⁾ Data from Manzer *et al.* (MS 1963). One tan is approximately 180 feet.

+ means 1-500 fish.

TABLE 14. Percentage age composition of coho salmon taken in Japanese high seas fisheries, 1959-1960, not including small numbers of other age groups¹⁾.

Region	Sample size		3 ₂		4 ₃		5 ₄	
	1959	1960	1959	1960	1959	1960	1959	1960
Aleutian ²⁾	437	264	29.1	28.8	63.8	65.9	7.1	5.3
Bering ²⁾		29		6.9		82.8		10.3
Kamchatka and Kurils ²⁾	936	1,027	36.5	23.1	58.8	70.2	4.7	6.7
Landbased Area A ³⁾		317		25.9		67.2		6.9
Landbased Area B ³⁾		167		21.6		72.4		6.0
Average	1,373	1,804	34.2	24.0	60.4	69.5	5.4	6.5

¹⁾ From data of the Japanese Fisheries Agency. See Manzer *et al.* (MS 1963) for designation of regions.²⁾ Japanese mothership fishery.³⁾ Japanese landbased fishery.TABLE 15. Average fork lengths (cm) of coho salmon from the Japanese high seas fisheries, 1957-1960, by region¹⁾.

		All ages			
		M	F		
1957 : Kamchatka-Kurils	June	53.5	52.6		
	July	54.1	54.7		
	June	55.7	55.3		
	July	55.7	55.3		
	July	56.3	55.4		
1958 : Kamchatka-Kurils	June	54.1	53.7		
	July	55.5	56.2		
	August	56.2	57.3		
	August	57.2	58.1		
	July	57.4	56.8		
Aleutian	August	56.8	57.9		
1959 : Aleutian	June	50.8	50.3	52.8	51.6
	July	54.0	52.6	54.6	55.0
	June	51.6	51.0	52.2	51.7
	July	53.5	53.8	54.0	54.2
	July	55.1	55.8	56.6	56.8
Bering Sea	August			55.0	55.1
Kamchatka-Kurils	June			54.5	53.6
	July	53.8	55.3	55.4	55.8

¹⁾ From data of the Japanese Fisheries Agency. See Manzer *et al.* (MS 1963) for designation of the different fishery regions.

description of the return routes of North American coho. There appears to be a general northward movement of coho in the Gulf of Alaska and towards the eastern Aleutians and the Alaska Peninsula throughout spring to late summer. Canadian long-lining in the Gulf in 1962 provided evidence that in the spring coho were present only in the southeastern limits of the Gulf. As the season advanced, with a progressive warming of more northerly waters, they appeared to have moved mainly in a northwesterly direction towards the center of the Gulf, where they became relatively concentrated by late June. Later they apparently dispersed shorewards and coho tagged in the open waters of the Gulf were subsequently recovered at points extending from the south side of the Alaska Peninsula to northern British Columbia (Fig. 15). In earlier years, coho that were recovered in western Alaska had been tagged south of Adak and coho tagged to the southeast of Kodiak Island were recovered from central Alaska to near the Alaska-British Columbia border. Coho salmon that had been tagged in British Columbia coastal waters usually made short migrations (as compared with chinook salmon tagged in the same area) and were recovered

TABLE 16. Average weights (kg) of coho salmon caught in different regions of the Japanese high seas salmon fisheries in 1960¹⁾.

Region		May		June		July		August	
		<i>M</i>	<i>F</i>	<i>M</i>	<i>F</i>	<i>M</i>	<i>F</i>	<i>M</i>	<i>F</i>
Aleutian :	Number			5	2	120	132	4	2
	Weight			1.93	1.91	2.65	2.72	2.11	2.55
Bering Sea :	Number			2	1			11	17
	Weight			3.18	1.75			2.54	2.48
Kamchatka-Kurils :	Number		2	50	34	467	462	10	7
	Weight		1.55	2.00	1.95	2.36	2.47	2.79	3.17
Landbased Area A :	Number					115	124	30	50
	Weight					2.55	2.56	3.02	2.94
Landbased Area B :	Number	1		13	11	75	72		
	Weight	1.35		2.43	2.14	2.20	2.16		

¹⁾ From data of the Japanese Fisheries Agency. See Manzer *et al.* (MS 1963) for designation of the different fishery regions.

TABLE 17. Average index of maturity of coho salmon taken in regions of the Japanese high seas salmon fisheries in 1960¹⁾.

Region		May		June		July		August	
		<i>M</i>	<i>F</i>	<i>M</i>	<i>F</i>	<i>M</i>	<i>F</i>	<i>M</i>	<i>F</i>
Aleutian :	Number			5	2	120	132	4	2
	Index			0.40	2.50	2.21	2.80	2.00	8.00
Bering Sea :	Number			1	1			11	17
	Index			1.00	1.00			5.36	6.35
Kamchatka-Kurils :	Number		2	50	34	467	462	10	7
	Index		2.50	0.20	1.62	2.17	3.10	3.20	4.14
Landbased Area A :	Number					115	124	34	50
	Index					2.53	2.84	3.12	3.26
Landbased Area B :	Number			13	11	75	72		
	Index			0.85	2.64	1.28	2.72		

¹⁾ From data of the Japanese Fisheries Agency. The index of maturity is the weight of the gonads expressed as a percentage of the total body weight.

TABLE 18. Lengths at tagging of nine coho salmon tagged by the United States in the Gulf of Alaska and recovered a year later.

Tagged			Recovered	
Location	Date	Fork length (cm)	Location	Date
55°42'N, 151°49'W	Sept. 5, 1958	31.0	Depoe Bay, Oregon	June 30, 1959
59°35'N, 140°41'W	July 16, 1961	27.0	Oregon coast	Aug. 9, 1962
56°54'N, 135°57'W	July 22, 1961	28.5	W. coast Vancouver Is.	July 3, 1962
56°54'N, 135°57'W	July 22, 1961	25.0	W. coast Vancouver Is.	Aug. 22, 1962
56°40'N, 135°38'W	Sept. 26, 1961	31.0	W. coast Vancouver Is.	June 24, 1962
60°13'N, 146°58'W	Sept. 16, 1961	27.0	Copper River	Sept. 5, 1962
58°23'N, 137°20'W	Aug. 16, 1961	28.0	S. E. Alaska	Aug. 28, 1962
59°33'N, 140°44'W	July 25, 1961	27.5	Strait of Georgia	Oct. 23, 1962
59°33'N, 140°44'W	July 25, 1961	25.0	S. E. Alaska	Oct. 23, 1962

in many directions from the tagging locations (Milne, 1957).

As mentioned earlier, the rate of migration of maturing coho salmon in the ocean is difficult to determine, mainly because of the unknown period of time between arrival and capture at the place of their recovery. Milne (1957) felt that both the feeding and spawning migrations of coho were relatively slow and that the fish wandered more than the other species. However, there have been instances of rates of migration for individual coho as high as roughly 30 miles per day—for example, from south of Adak to the East Kamchatkan coast and to western Alaskan waters. These are considerable distances, but the relative proximity to their spawning streams may have been an influencing factor subscribing to a faster rate of travel than might have been in effect earlier in more southern waters. As an example of a coho tagged and recovered on the high seas (as distinct from coastal or stream recoveries) in North Pacific waters well removed from coasts, the following recovery may be cited: tagged at $43^{\circ}44'N$, $170^{\circ}E$ on May 24, 1959; recovered at $45^{\circ}N$, $155^{\circ}E$ on July 21, 1959; minimum distance travelled roughly 650 miles; days out 58; average rate of travel 11.2 miles per day.

On the assumption that they returned to their native streams, the recoveries mentioned earlier of coho tagged at 0-ocean age provide interesting information on the ocean movements of the immature fish. They had moved primarily northward and westward in the Gulf. Some had travelled over 1,000 miles during their first months of ocean residence. They must have moved southward during their first ocean winter, then northward again as mature fish, during their last spring or early summer.

VERTICAL DISTRIBUTION

Information on the vertical distribution of coho salmon in the sea is rather fragmentary. In Canadian experiments with sunken gillnets in 1957 and 1959 a few coho were taken at depths between 20 to 80 feet (6–24 m), but considerably more were captured near the surface between 0–20 feet (0–6 m). Japanese experiments in 1960 (Machidori, 1961) in the western North Pacific and Bering Sea indicated that coho salmon were probably limited to depths down to 10 m (33 ft). Further experiments in 1962 did not add to this knowledge (Machidori and Oseko, 1962).

Coho salmon have frequently been captured by vertical longlines from the Canadian weather ship vessels at Station "P" in the Gulf of Alaska ($50^{\circ}N$, $145^{\circ}W$). The actual depths at which these fish have

been hooked is difficult to determine because of the forward movement of the vessels, but estimated depths up to 150 feet (46 m) have been reported.

Milne (1955) has recorded that, when testing trolling lures off the west coast of Vancouver Island, coho salmon were taken at depths of from 5 to 10 fathoms (9–18 m), but most of them at about 5 fathoms.

Fishermen prosecuting the troll fisheries in coastal waters of southeast Alaska and British Columbia are of the general opinion that coho salmon swim closer to the surface than do chinook salmon. Dr. R. Parker of the Biological Station at Nanaimo, British Columbia, once determined that chinook salmon in coastal waters occurred mainly below the thermocline and coho salmon mainly in and above the thermocline (personal communication).

THE GEOGRAPHICAL ORIGIN OF COHO SALMON ON THE HIGH SEAS

As has been mentioned earlier, the racial origin of coho salmon taken on the high seas has hardly been examined. Some positive information has been derived from the results of tagging operations and, in addition, the location and timing of catches of maturing coho in fishing operations give indications of the probable destinations of these fish.

TAGGING (FIGS. 9 TO 14) AND HIGH SEAS CATCHES

In the northern North Pacific Ocean, coho salmon of Asian origin have been found as far to the east as directly south of Adak Island, that is, to almost $175^{\circ}W$ longitude. Thus, during 1956–1962, from tagging south of Adak by the United States in 1957 and by Japan in 1959, there have been six recoveries on the East Kamchatkan coast. From considerable taggings farther to the west in the North Pacific, including numbers tagged considerably farther to the south, all of relatively many recoveries have been from Asian coastal waters and streams, including the east and west coasts of the Kamchatka Peninsula and the Okhotsk Sea coast, or from the high seas either close to or appreciably westward of the tagging locations.

Very few coho had been tagged in the Bering Sea up to 1962 and none east of the 180° meridian. There has been but one recovery (in the Kamchatka River) from a tagging location at about $172^{\circ}E$ longitude, $55^{\circ}N$ latitude.

The presence of mature coho from western Alaska directly south of Adak has been indicated by the

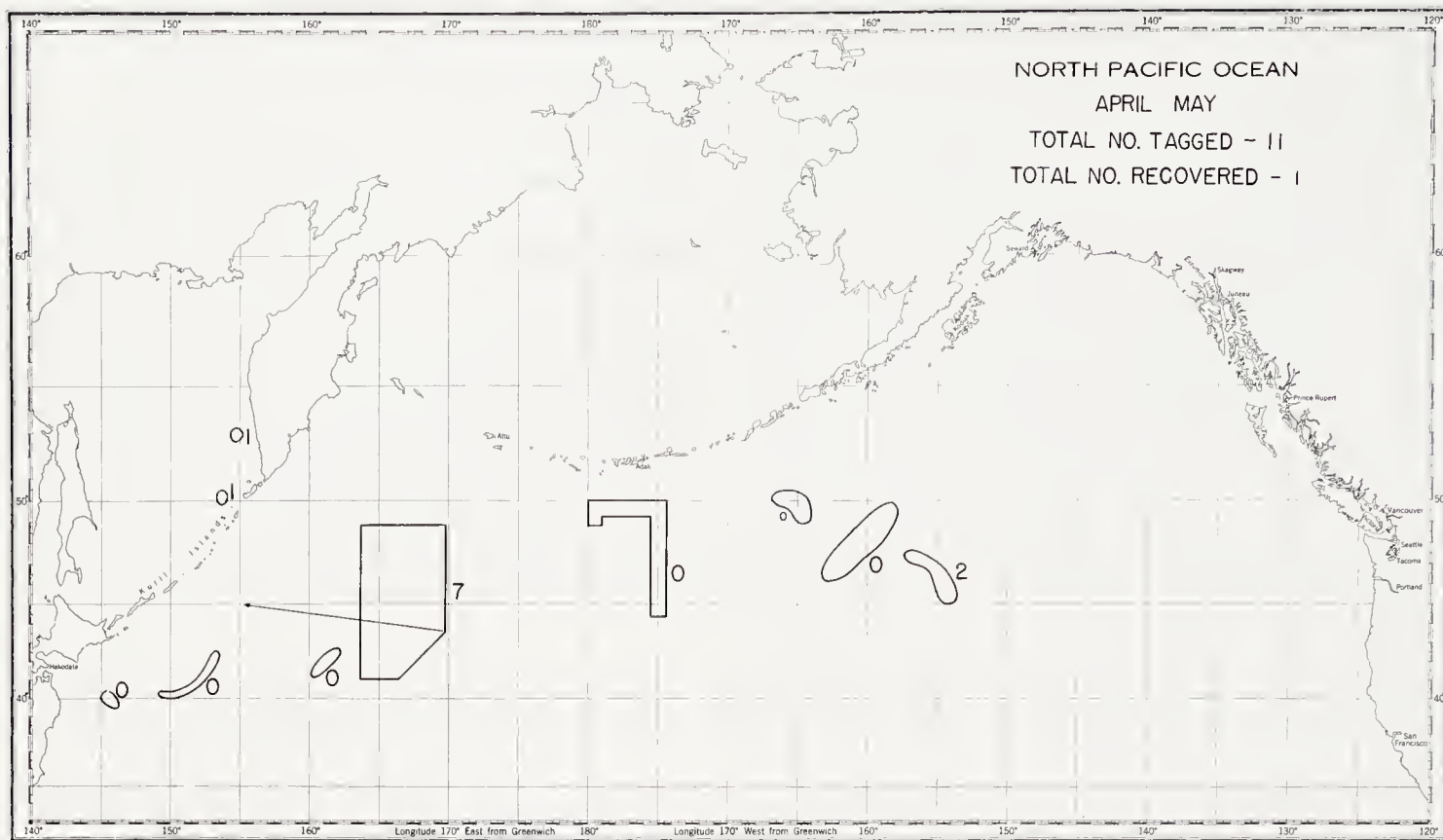


FIGURE 9. Japanese tagging, 1958-1962 ; numbers of coho salmon tagged and recovered, by month of tagging—April, May.

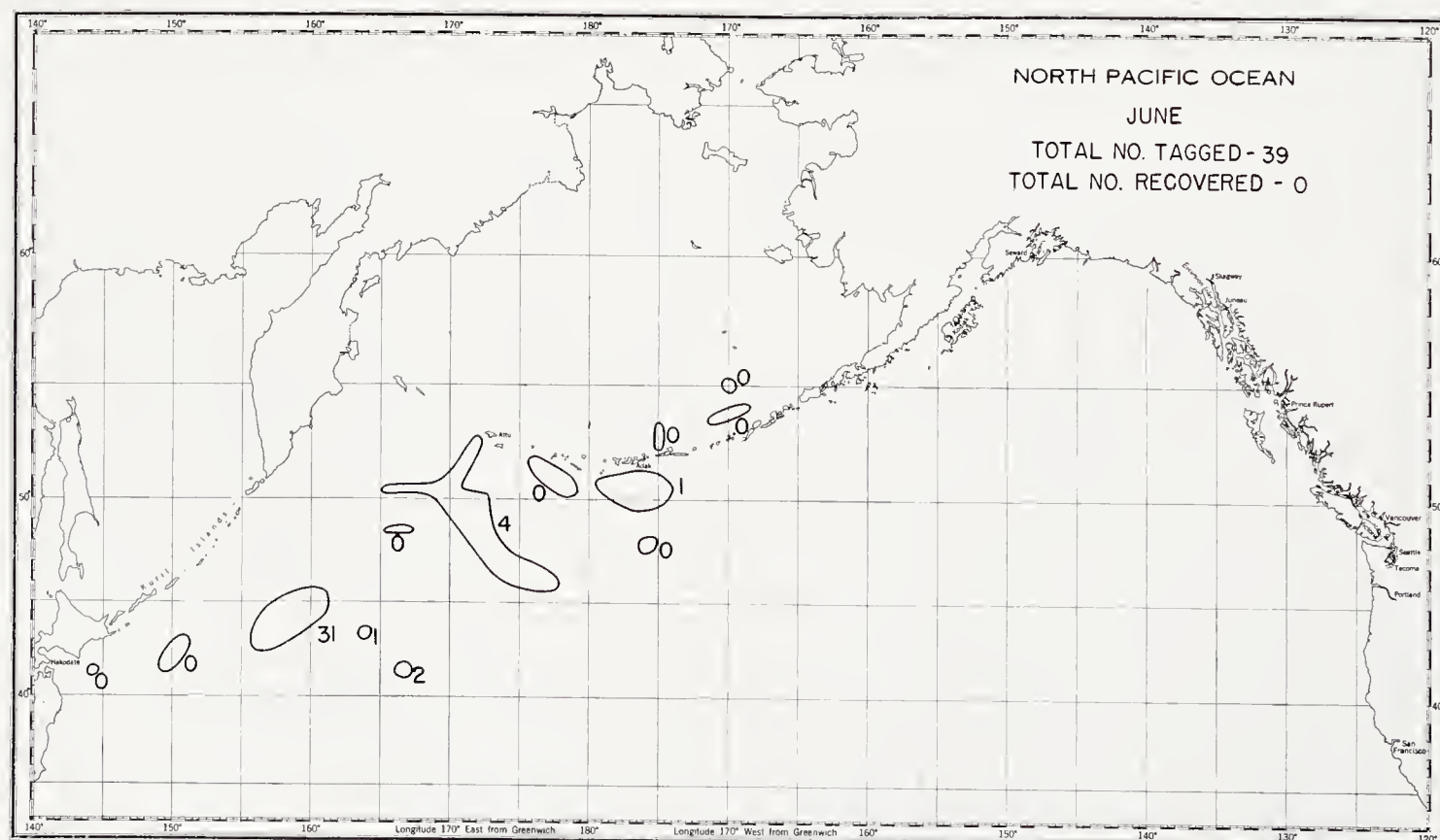


FIGURE 10. Japanese tagging, 1958-1962 ; numbers of coho salmon tagged and recovered, by month of tagging—June.

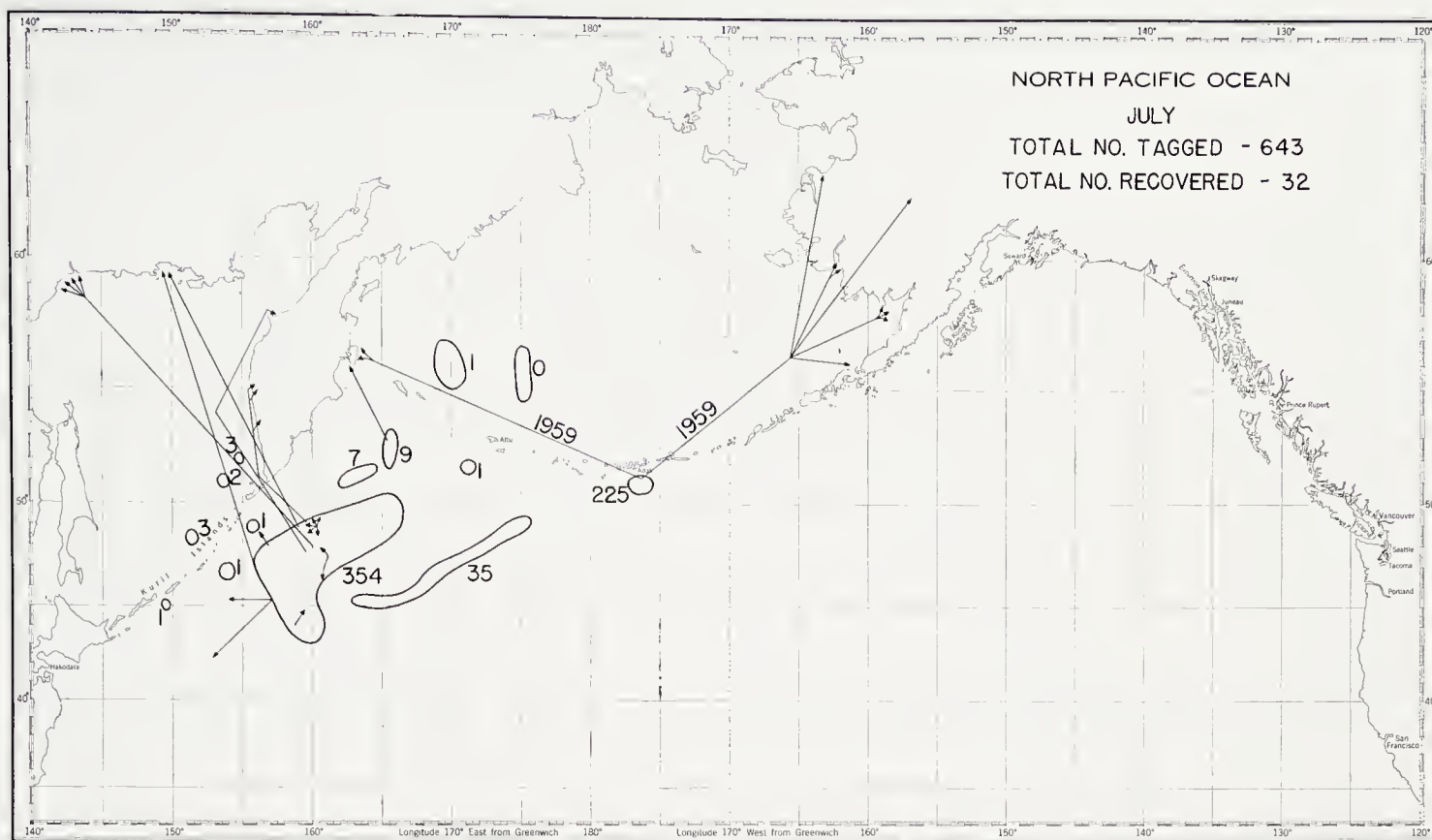


FIGURE 11. Japanese tagging, 1958-1962 ; numbers of coho salmon tagged and recovered, by month of tagging—July.

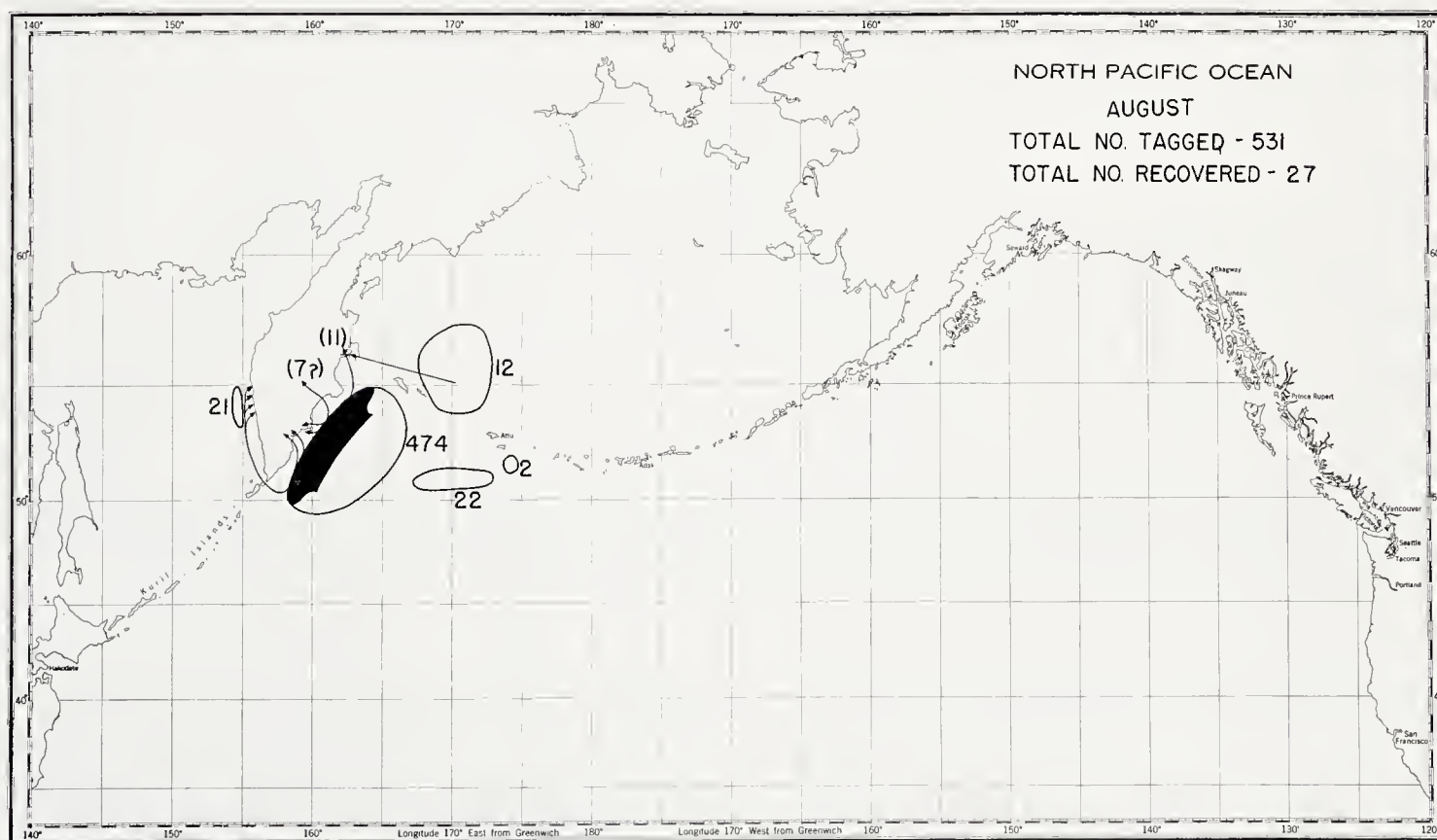


FIGURE 12. Japanese tagging, 1958-1962 ; numbers of coho salmon tagged and recovered, by month of tagging—August.

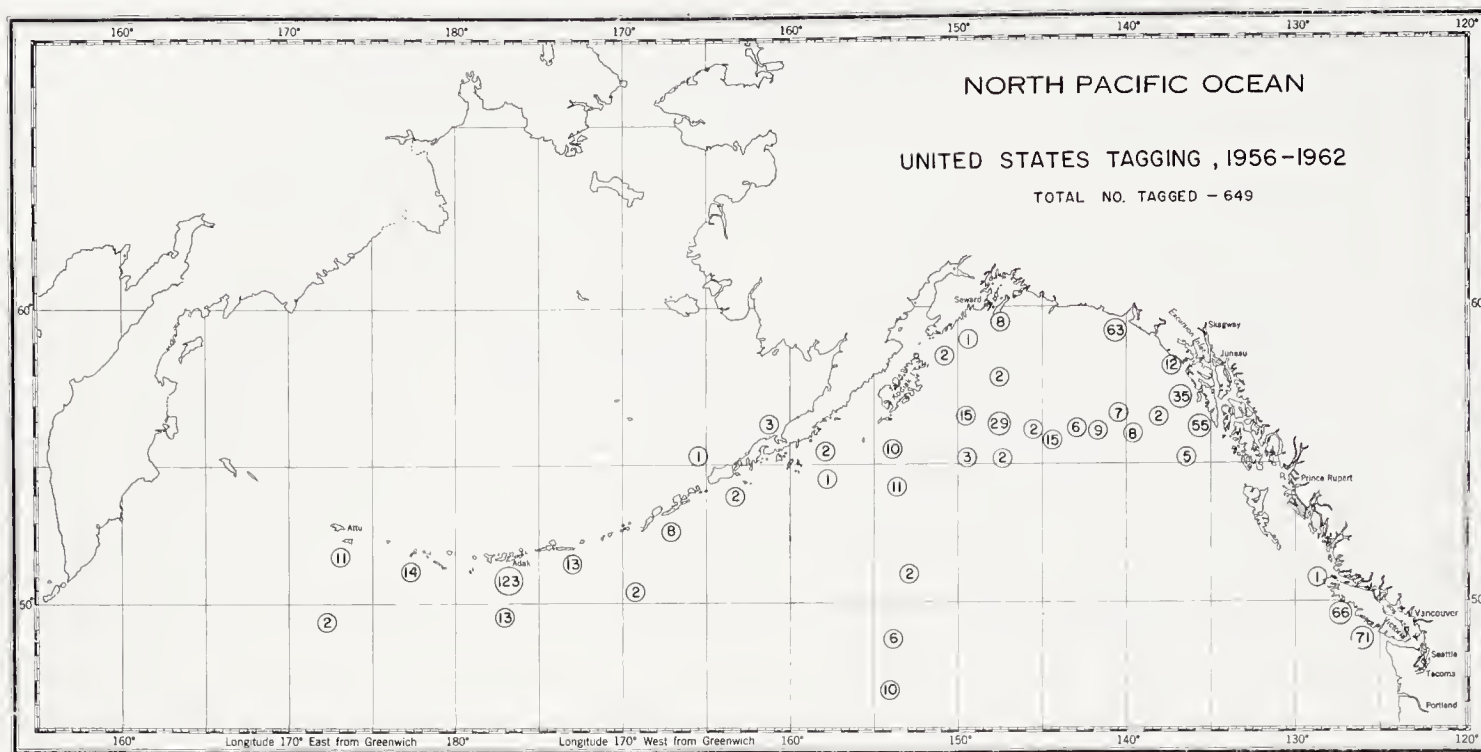


FIGURE 13. United States tagging, 1956-1962 ; numbers of coho salmon tagged.

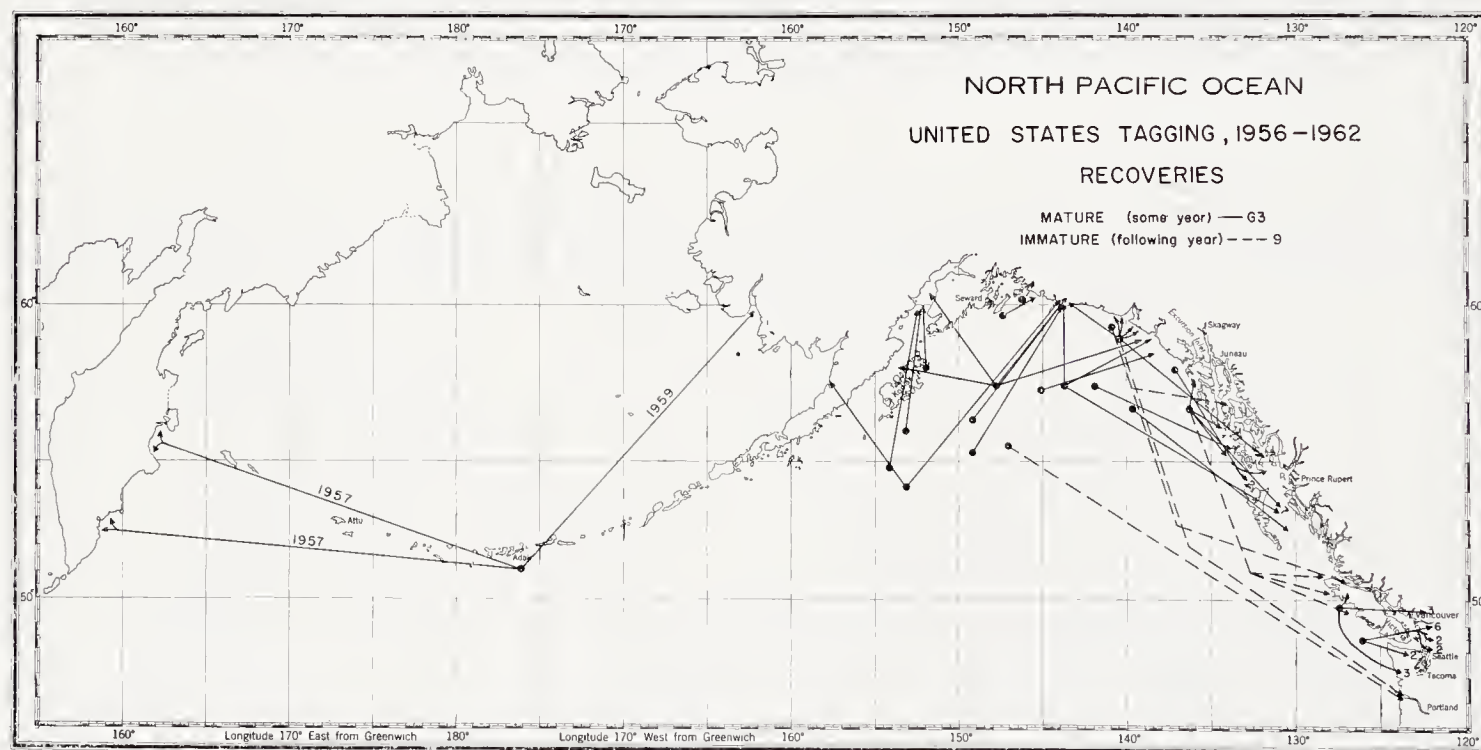


FIGURE 14. United States tagging, 1956-1962 ; recoveries of mature (solid line) and immature (broken line) coho salmon.

following recoveries from Japanese and United States taggings in 1959: Yukon River, 2; Kuskokwim River, 3; Bristol Bay, 3; and north shore Alaska Peninsula, 1. These indicate the known westward limit of the occurrence of North American coho in the North Pacific Ocean.

All other recoveries in North America of coho

salmon tagged during 1956-1962 have come from taggings in the Gulf of Alaska, the westernmost tagging location represented by such recoveries being approximately 152°W longitude.

These results indicate, therefore, that the coho salmon that are found in the western North Pacific must be predominantly of Asian (specifically, of

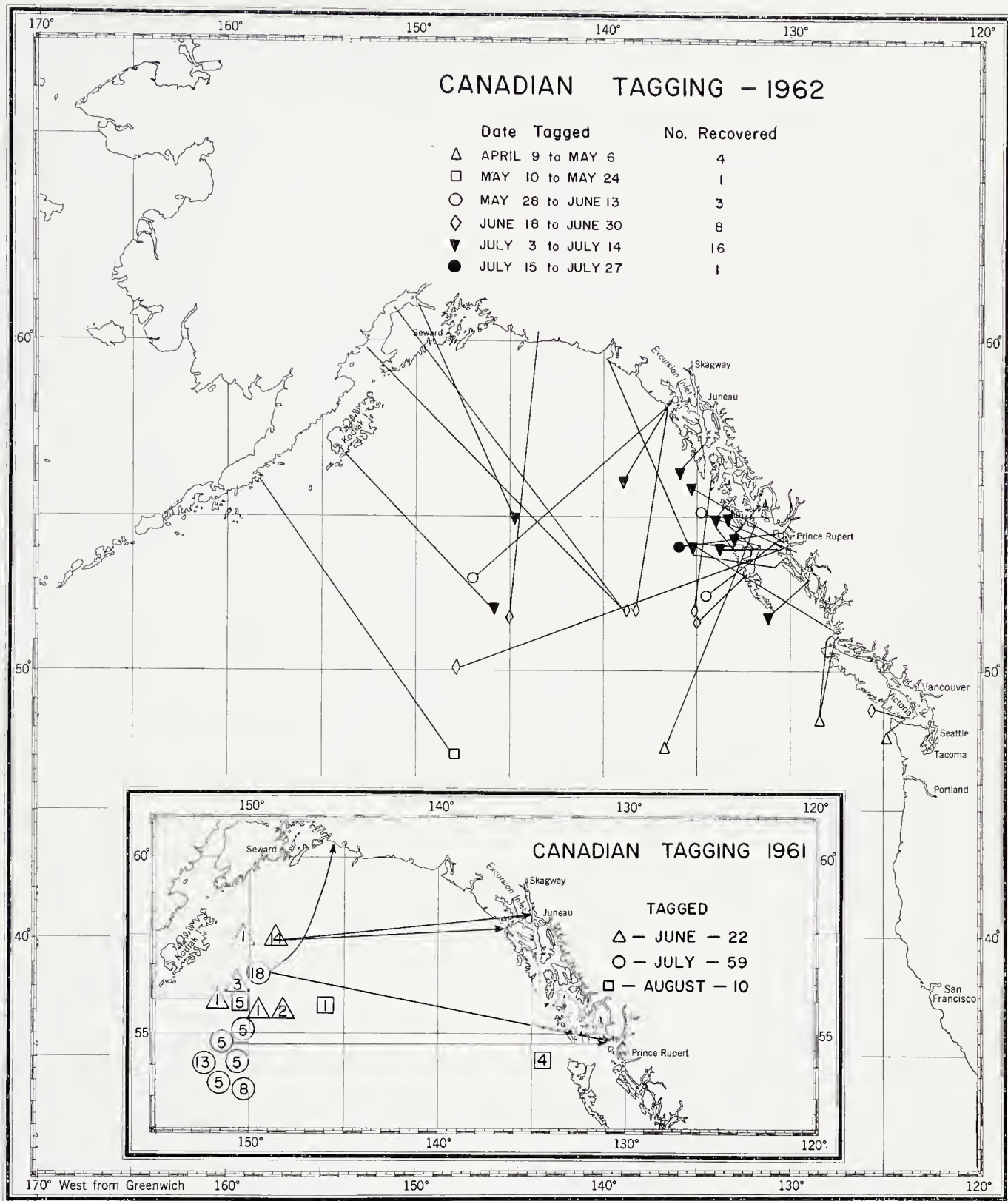


FIGURE 15. Canadian tagging in 1961 (inset) and 1962; recoveries of coho salmon made in the same year of tagging.

U.S.S.R.) origin and that Asian coho may occur eastward along the south side of the Aleutian Chain at least as far as almost 175°W longitude. Western Alaskan coho are known to have occurred at least as far westward as 176°W longitude along the south Aleutian Chain. There have been no recoveries within the boundaries of the Gulf of Alaska or further

south from any taggings that were made outside of the Gulf west of 160°W longitude.

Some coho that were tagged south of the Kamchatka Peninsula entered the Bering Sea and were captured at points along the East Kamchatkan coast. Taggings in the Bering Sea itself were too few to

permit definitive statements regarding the origin of coho salmon taken there by commercial and research vessels.

The great bulk of the coho salmon that are taken in the Japanese mothership and landbased fisheries is captured relatively close to the Asian coastline, either to the east of Hokkaido and the southern Kuril Islands or southeast of the Kamchatka Peninsula. Some sampling and age determinations indicate that these are maturing fish (see Tables 14 to 17). They arrive in these northwesterly waters late in the season, mainly during late July and August. Somewhat later, coho runs appear in U.S.S.R. coastal waters and streams, in general, beginning with the runs to the east coast of Kamchatka, followed by those to the west coast of Kamchatka and the Okhotsk Sea coast. Their proximity to the Asian coast at this time (in contrast with their separation from the western shores of North America), their maturity and the subsequent arrival of coho runs in U.S.S.R. streams indicate that these relatively large concentrations of coho salmon found in the more westerly areas of the northwest Pacific Ocean must be of U.S.S.R. origin. The tagging results described above support this conclusion.

Because commercial salmon fishing in western Canada and the United States is limited to coastal waters, there is considerably less information regarding the occurrence of coho salmon in the eastern North Pacific. As a result, less can be said at this time about the known distribution of North American coho on the high seas. Gillnet catches by research vessels during 1956–1962 have indicated that from July to September important numbers of coho appear south of the Aleutians westward from at least as far east as Adak Island (176°W). Tagging has shown that both Kamchatkan and Western Alaskan coho may be present in the vicinity of Adak Island during some of this period at least. Farther to the east the catches have been more sparse until made within coastal waters of the Gulf of Alaska. Again, considering that these are maturing fish and considering the time and place of their capture in relation to the timing of the coho runs to North American streams, it would seem very unlikely that many coho occurring in the North Pacific Ocean east of about 175°W longitude could be of Asian origin.

INTERMINGLING BETWEEN ASIAN AND NORTH AMERICAN COHO SALMON

Positive evidence of some intermingling between mature Asian and North American coho salmon has come from the recoveries of tagged salmon. Specifi-

cally, the intermingling (in the sense that both were present in the same area at the same time) occurred between coho salmon from western Alaska and from East Kamchatka.

In July 1959, Japan tagged 225 coho salmon directly south of Adak (at approximately 176°W longitude), from which eight were later recovered in western Alaska and two in East Kamchatka (Fig. 11). This is the only substantial instance of definite intermingling between coho salmon, in the sense described above. However, in this same general area, from 43 coho tagged by the United States in July 1957 and from 19 tagged by the United States in July 1959, there were four recoveries in East Kamchatka from the 43 and one in western Alaska from the 19 (Fig. 14).

These data in themselves are not sufficient to indicate the extent of intermingling, in terms of numbers of fish involved or of annual variations, particularly in view of the fact that the true magnitudes of the western Alaskan and East Kamchatkan coho stocks are not known.

As indicated earlier in this report, the concentrations of coho salmon that appear during late July and August in the western North Pacific and western Bering Sea, in the regions of the Japanese landbased and mothership fisheries, are probably wholly, or at least almost wholly, of U.S.S.R. origin. When these fish do appear in more northern latitudes (north of 45°N), most are already well to the west, including probably the bulk of those that approach southeast Kamchatka along the south side of the Aleutian Chain.

Knowledge of the ocean distribution of maturing coho salmon originating in streams of the Gulf of Alaska and farther south is still very limited. However, such evidence as has been derived from research vessel catches and tagging recoveries (as described earlier) suggests that it is unlikely that many would be present far to the west of the Gulf during their last several months in the sea.

In view of these considerations it is therefore concluded that, excepting some intermingling in some years between western Alaskan and East Kamchatkan coho, it is improbable that extensive intermingling ever occurs between maturing Asian and North American coho salmon.

With the exception of some preliminary analyses of the scale characteristics of North American and Asian coho salmon by Sato (1961b), no racial studies of coho salmon with a view to determining the geographical origin of high seas catches have yet been attempted.

Sato's work gave some indication that 3₂ coho collected off East Kamchatka were mainly of the Asian type, whereas samples of the same age class taken off southeast Alaska were mainly of the North American type.

SUMMARY

(1) On the Pacific coast of North America, coho salmon occur from at least as far north as Cape Thompson in the Chukchi Sea southwards into the State of California. They are present in eastern Asia at least as far north as the Anadyr River, southwards to the Amur Firth, and on islands in the Okhotsk Sea and in Hokkaido.

In Asia, the great bulk of coho salmon is produced in the streams of East and West Kamchatka. The major producing areas in North America extend from central Alaska into the State of Washington.

(2) A brief narrative description of the life history of coho salmon from spawning to their return from the ocean is given.

Almost all coho salmon on both continents spend one or two years in fresh water before they migrate to the sea and almost all of those that survive return as mature adults late in the year following that in which they entered the sea.

(3) It is a characteristic of coho salmon that they spawn in numerous small coastal streams and in the tributaries of larger rivers. The total production of coho salmon on both continents is thus an aggregate of the production from many rivers. This feature makes estimating the total stock size of coho salmon virtually impossible, because spawning escapements cannot be determined. Furthermore, the fishing intensity for coho salmon in different regions of the two continents is not consistent. For these reasons, comparisons of the total production of coho salmon in Asia and North America have been made on the basis of average catches in the fisheries in recent years.

(4) Coho salmon catches in Asia and North America are compared for the period 1954–1961, 1954 being the first year of a major Japanese mothership operation in the North Pacific Ocean and Bering Sea. For reasons given in the text, Japanese catches of coho salmon in the mothership and landbased fisheries are apportioned to Asian stocks.

The average annual catch of Asian coho salmon during 1954–1961 has been roughly 4.6 million (U.S.S.R. coastal, 1.5 million ; Japanese mothership,

1.9 million ; Japanese offshore driftnet fishery, 1.2 million). The comparable figure for North America (including sport fishing catches) has been roughly 6.5 million. Because it is known that the catch statistics for coho salmon on both continents are not complete, the ratio of Asian to North American catches during 1954–1961 may be described as in the order of five to seven million annually.

(5) The time of return from the high seas into coastal waters of maturing coho salmon is similar on the two continents. It is late in the season and prolonged, taking place mainly during late July and August. Generally speaking, the coho runs follow those of the other species, excepting the "autumn" runs of chum salmon and the late runs of chinook.

(6) Coho salmon have been found across the width of the northern North Pacific Ocean and intermittently throughout the Bering Sea where fishing has been attempted. In the eastern half of the North Pacific, a coho salmon has been caught as far south as 45°N latitude by an INPFC vessel, but they are also known to occur even farther south, at considerable distances from the southern California coast. They have been taken as far south as 42°30'N latitude in the western North Pacific.

(7) In the western North Pacific Ocean, large numbers of maturing coho salmon begin to appear in more northerly waters (north of 40°N latitude) during late June. During late July and August, concentrations of these fish approach the southeast coast of Kamchatka, mainly from the south and southeast, but some also from along the south side of the Aleutian Chain. Some proceed to streams on the coast of East Kamchatka and farther north in the Bering Sea, by way of the Aleutian passes and from more directly south, off southeast Kamchatka.

The concentrations that appear east of the Kuril Islands and off southeast Kamchatka also provide runs to the coast of West Kamchatka and to streams on the mainland coast of the Okhotsk Sea.

(8) Coho salmon appear to be more widely dispersed in the eastern half of the North Pacific, including the Gulf of Alaska, than in the western half. Canadian research in 1962 did indicate a degree of coho salmon concentration occurring during mid-summer in the central area of the Gulf, but they are probably most concentrated only after they have reached coastal waters. Here the catches in the commercial fisheries increase sharply during July and August ; by September coho salmon are almost wholly absent in offshore waters.

(9) Catches of a few immature (0-ocean-age) coho have been reported from the Gulf of Alaska and in the Okhotsk Sea.

(10) Sampling in the Japanese mothership fishery in 1959 and 1960 has shown that coho of ages 3_2 and 4_3 made up 90 percent or more of the age composition of the catch and that among these the 4_3 fish were the more numerous. In the Gulf of Alaska, 3_2 fish constituted more than 90 percent of the catches of coho salmon made by Canadian research vessels in 1957 and 1958.

(11) Various evidence indicates that coho salmon in the sea swim relatively close to the surface and that they occur in greatest abundance within the upper 10 m layer.

(12) The subsequent recovery of nine coho salmon tagged in the Gulf of Alaska as immature, 0-ocean-age fish indicated that during their first few months in the ocean they had travelled great distances (one at least 1,200 miles) and had grown rapidly (up to 31 cm). (This statement assumes that the streams in which they were recovered were, or were close to, their natal streams.)

(13) Tagging results, the condition of maturity, the proximity to Asian shores, the time of arrival in Asian coastal waters and the subsequent appearance shortly thereafter of runs of coho in Asian streams indicate that the coho salmon that appear during late summer in the western North Pacific and Bering Sea are probably wholly, or at least almost wholly, of Asian (specifically, U.S.S.R.) origin. Coho salmon of East Kamchatkan origin have been found along the south side of the Aleutian Chain to at least as far east as about 176°W longitude.

For similar reasons, it was concluded that, excepting the known occurrence of East Kamchatkan coho directly south of Adak Island (roughly 176°W longitude), coho salmon found in the eastern half of the North Pacific and Bering Sea were probably wholly, or at least predominantly, of North American origin. Western Alaskan coho were found as far to the west as directly south of Adak Island.

(14) Tagging experiments gave positive evidence of some intermingling in one year between maturing East Kamchatkan and western Alaskan coho directly south of Adak. Additional tagging results also indicated that East Kamchatkan and western Alaskan coho had been present in other years at least that far to the east and west, respectively, south of the Aleutians (although not necessarily at the same time, since

the recoveries from those areas were not made in the same year).

Apart from this known intermingling between East Kamchatkan and western Alaskan coho, it is considered to be very unlikely that extensive intermingling ever occurs between maturing coho salmon from the two continents.

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SALMON OF THE NORTH PACIFIC OCEAN—PART IX COHO, CHINOOK AND MASU SALMON IN OFFSHORE WATERS

2. CHINOOK SALMON IN OFFSHORE WATERS

by

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Biological Laboratory, Seattle, Washington, January 1964

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INTRODUCTION

The International North Pacific Fisheries Commission has requested the preparation of a joint comprehensive report on the salmon of the North Pacific Ocean and the Bering Sea. Part IX of this comprehensive report deals with coho, chinook and masu salmon in offshore waters. The material to follow comprises the chinook salmon section of Part IX. The objective will be to assess the status of our knowledge concerning the qualitative and quantitative aspects of chinook salmon in offshore waters. Such assessment requires (1) a knowledge of the life history of the young in fresh water and in coastal areas and the distribution of chinook in inshore areas; (2) knowledge of the stocks in North America and in Asia and the distribution and abundance of chinook in offshore waters; and (3) appraisal of these various data to draw conclusions regarding the qualitative and quantitative aspects of the distribution of chinook salmon in offshore waters.

Chinook salmon (*Oncorhynchus tshawytscha*) have been found along the North American coast from the Ventura River in California (Cobb, 1931) north to the Chukchi Sea (Smith, 1960). In Asia, they occur in some large rivers in Hokkaido (Hikita, 1956), in Sakhalin (Shmidt, 1950) and northward at least to the Anadyr River (Kaganovski, 1933). The principal areas of production in Asia are located on the Kamchatka Peninsula. Except for Smith's report (1960), the occurrence of chinook salmon in North American and Asian arctic areas is neither established nor defined in available literature.

Chinook salmon spawn principally in the larger rivers and their tributaries. Although the major North American populations return to the Sacramento,

Columbia, Fraser, Skeena, Nushagak and Yukon Rivers, important runs occur in many other rivers.

Along the North American coast, chinook are taken principally in commercial troll and gillnet fisheries, while important numbers are taken in various sport fisheries. Significant numbers are caught in the Japanese mothership and landbased fisheries and in the coastal and river fisheries of Kamchatka and the Okhotsk Sea. In the period 1954 through 1961, the combined commercial catches of Japan and Russia varied from 96,000 to 250,000 chinook salmon, as compared with 2,456,300 to 3,664,200 for the United States and Canada combined. With the exception of masu salmon, the combined commercial catch of chinook salmon is below that of all other species of Pacific salmon. For example, in 1956, 3,777,000 chinook were caught commercially by Japan, Canada and the United States, as compared to 10,442,000 coho, 29,267,000 sockeye, 34,695,000 chum and 84,949,000 pink salmon. In the same year, an additional 110,000 chinook salmon were taken in the Soviet coastal fisheries and 731,000 in the sport fisheries of Canada and the United States.

LIFE HISTORY

IDENTIFICATION OF RUNS AND RACES

Before describing the life history of chinook salmon, definitions of a "run" and a "race", as used in this paper, should be established, since inherent biological differences are implied which have a direct bearing on time of migration to salt water, perhaps on the extent of marine migration, on time of return to coastal and river areas and on time of spawning.

For purposes here, a "run" is defined as a seasonal appearance of chinook salmon in a coastal or river area, first in small numbers which usually increase rather rapidly to a peak and then decline, with small numbers sometimes continuing to appear for extended periods of time. A "race" is defined as a population of chinook salmon which will spawn in a particular river or tributary at a particular time of the year. A single race may make up all or only part of a run.

Many river systems have more than one run or more than one race of chinook salmon. Each run may include more than one race, each apparently a separate biological entity. Fry (1961), for example, described three runs to the California central valley—a fall run, a spring run and a winter run. Gharrett and Hodges (1950) reported that in coastal Oregon streams a spring run of chinook entered and passed

through the fishcry, followed by a later fall run. The Columbia River has spring, summer and fall runs of chinook salmon. All spawn in the summer and early fall and winter months, in contrast to the Sacramento River chinook, where the fall run spawns in October to March, the winter run from May to July and the spring run in September and October. The three Columbia River runs of chinook are identifiable in the commercial fisheries of the lower river and estuary (Figure 1, using 1960 for illustration purposes), as well as at the counting stations at Bonneville Dam. These runs also maintain their identity at The Dalles, McNary and Rock Island Dams farther upstream. The chinook counts from The Dalles and McNary Dam are not included in Figure 1, but they may be found in U.S. Army Corps of Engineers (1960).

Many coastal and Puget Sound streams of Washington, and the smaller British Columbia coastal rivers, may have a spring and a fall run similar to those of Oregon (Smoker, 1954). In the Fraser River, chinook may first appear in the commercial

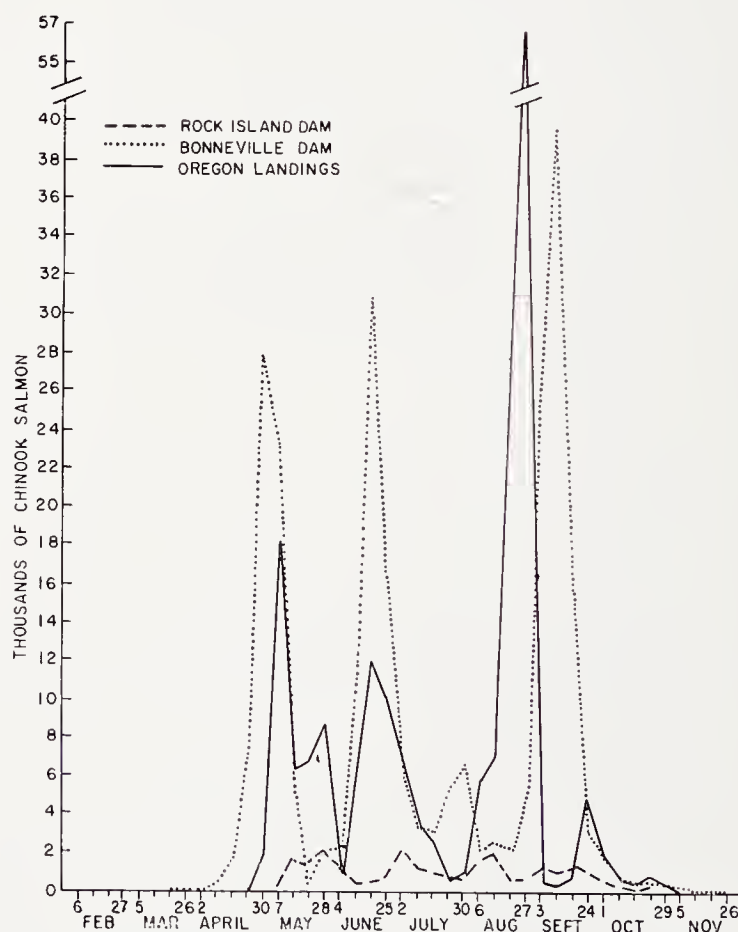


FIGURE 1. Number of chinook salmon caught by Oregon in the Columbia River and counts of chinook salmon at various dams on the Columbia River, 1960. Data from U.S. Army Corps of Engineers (1960), Zimmer and Davidson (1962) and INPFC Statistical Yearbook 1960.

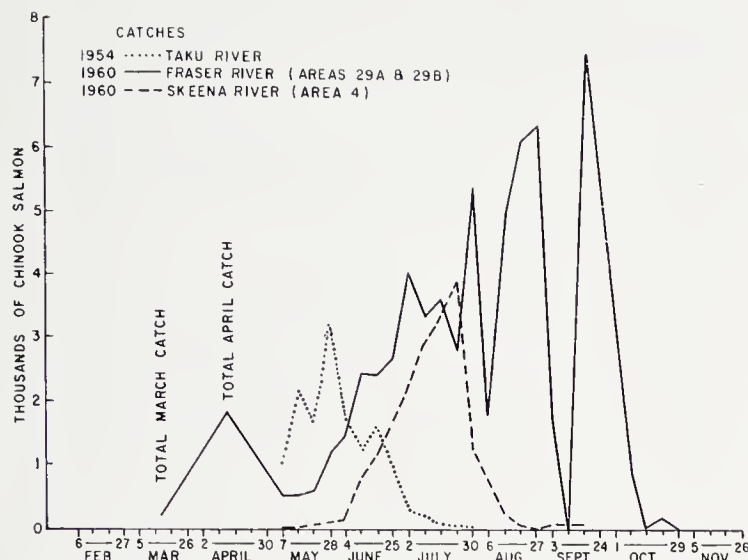


FIGURE 2. Gillnet catches of chinook salmon in the Taku, Skeena and Fraser Rivers. Data from Canada Department of Fisheries (1960) and Weberg and Garceau (1956).

fishery near its mouth as early as January, rising to maximum numbers in August and September and are present into October and even December in some years. Figure 2 shows the gillnet catches near the mouth of the Fraser River for British Columbia statistical areas 29A and 29B for 1960, selected for illustration purposes. The major intra-season declines are attributable to changes in regulations and there is no gross evidence of more than one run. Babcock (1931), on the other hand, stated that the early Fraser River chinook were destined for the headwaters, which implies existence of separate races. Passage of these races through the commercial fishery may overlap to the extent that they are not identified by the gillnet catches alone.

The chinook landings listed in the British Columbia catch statistics are also tabulated in terms of numbers classified as red, white and jacks¹. The percentages of these three commercial categories in each week's total chinook catch are shown for the Fraser River (statistical areas 29A and 29B) for 1960 in Figure 3. It may be seen that early in the season the catches were almost exclusively of red chinook with only small percentages of white chinook and jacks. The numbers of red chinook declined through the season and rose only slightly near the end of September. The numbers of white chinook rose steadily until July, remained relatively constant through July and August and reached a peak in September. Jack chinook

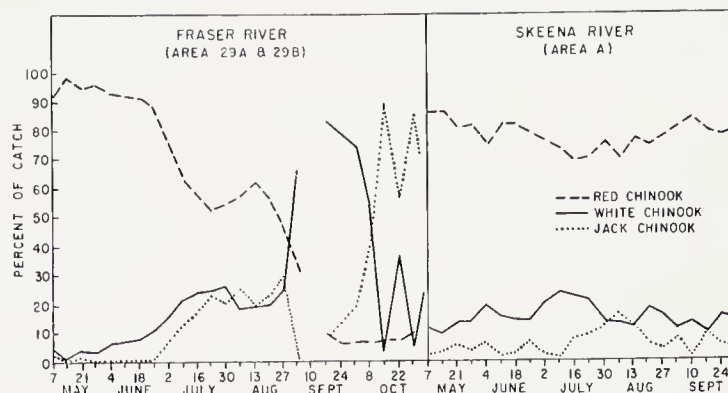


FIGURE 3. Composition (in percent) of weekly catches of chinook salmon in the Fraser and Skeena Rivers in 1960, based on their commercial classification as red, white, or jack chinook (see footnote, page 43). Data from Canada Department of Fisheries (1960).

comprised only a very small proportion of the catch through May and June, with the percentage rising in July and peaking in October. This change in catch composition, when compared to the Fraser River catch curve in Figure 2, is substantial evidence of the existence of different races of chinook within the Fraser River watershed and that the classifications of red, white and jacks may be indices of some possible use in race identification.

The commercial catches of the Skeena and Taku Rivers (Figure 2) were also examined for evidences of more than one run of chinook salmon. For this purpose, the 1960 gillnet catches of statistical area 4 were used for the Skeena River. The Taku River data were taken from Weberg and Garceau (1956) for the year 1954, which was selected as being typical of the published catch data for the years 1945 through 1954. For both the Skeena and Taku Rivers, the commercial catches offer no evidences of more than one chinook salmon run. Also, Parker and Kirkness (1951) recognized only one chinook run in the Taku commercial fishery. It might be noted in Figure 2 that the Taku run reaches a peak earlier than either the Skeena or Fraser run. The Skeena River run is apparently of shorter duration than the Fraser River run and it reaches a peak earlier in the season.

The Skeena River data for percent composition of red, white and jack chinook were plotted in Figure 3 for evidences of changes in racial composition, as were the data for the Fraser River already presented (similar statistics are not available for the Taku). A comparison with Figure 2 again suggests the existence of different races, but not to the degree apparent for the Fraser River.

The rather meager data on weir counts for a number of western Alaskan streams (U.S. Department of

¹ Separation of red and white chinook is made on the basis of flesh color, red chinook commanding a higher price than white chinook. Jacks are chinook salmon of either flesh color weighing less than six pounds.

Commerce, 1931–1940), indicate single chinook salmon runs that arrive in late June, July, or August, depending on the particular stream.

Gilbert (1922) stated that the Yukon River run starts around the first of June and is over in about three weeks, the time factor again indicating the presence of only a single run.

The trend indicated in the above examples, ranging from the Sacramento River to the Yukon River, is for a greater number of chinook salmon runs to be found in the rivers to the south, with the number of runs dropping to one to two at mid-latitudes and then to only one in more northern waters. The data also show differences in the time of arrival of chinook salmon runs to various rivers and that the peaks of spring or fall or other runs may vary from river to river. It is also apparent that catch statistics do not always provide enough information to separate races of chinook salmon in the absence of other biological data.

Within a single watershed, a particular run in the commercial fishery may be composed of a number of different races, each bound for a separate tributary. This is particularly true of the major watersheds, such as those of the Sacramento, Columbia and Fraser Rivers. Within their broad geographical boundaries, these watersheds include high altitude streams that depend on melting snows for water, vast arid areas which become extremely hot in the summer and sometimes extremely cold in the winter, and coastal drainages that depend upon seasonal rains for water. The various tributaries originating and flowing through these different climates offer, at one time or another during the course of the year, conditions suitable for migration and spawning of adults, hatching and rearing of young and their feeding and transport to the sea. It is more than coincidence that chinook salmon occur and spawn in particular tributaries at a particular time. It is also reasonable that such things as climate, geography and relationships with other aquatic life have at least some influence on the life history of the species.

The runs described by Fry (1961) in the Sacramento River may also be identified as races, since the fall run usually spawns in the period October to March, the spring run in the following September and October, and the winter run from May to July.

The spring chinook run in the Columbia River commercial fishery includes races destined for such diverse places as some of the tributaries of the Willamette, Snake and Wenatchee Rivers. In the Fraser River, there are spring run races to the Nechako,

Bowron, Quesnel and other tributary rivers. In the summer and fall there are late run races in Harrison River and elsewhere. On the Sacramento River, there are spring run races destined for the Keswick Dam area, Battle Creek, Mill Creek and tributaries. A similar list could be made to illustrate summer, fall and winter runs where they occur.

Even in the rivers to the north where a single run is apparent, the racial identities are not lost in the tributaries. The Taku River, for example, has separate races that spawn concurrently in the Nahlin, Nakina and other tributaries. It is unfortunate that,

TABLE 1. Kilograms of chinook salmon landed at Ozuchi, Iwate Prefecture, Honshu, Japan, by 10-day period in 1960 through 1962¹⁾.

10-day period		1960	1961	1962
<i>January</i>		13.7	6.6	—
	Early	9.8	3.9	—
	Middle	3.9	2.7	—
	Late	—	—	—
<i>February</i>		—	—	—
<i>March</i>		6.4	—	31.9
	Early	—	—	—
	Middle	5.0	—	10.3
	Late	1.4	—	21.6
<i>April</i>		—	68.0	*
	Early	—	—	34.9
	Middle	—	—	*
	Late	—	68.0	*
<i>May</i>		144.1	706.1	—
	Early	15.8	83.8	—
	Middle	128.3	413.7	—
	Late	—	208.6	—
<i>June</i>		7.5	29.2	—
	Early	—	13.0	—
	Middle	7.5	8.5	—
	Late	—	7.7	—
<i>July</i>		—	—	—
<i>August</i>		—	—	—
<i>September</i>		—	—	—
<i>October</i>		—	—	—
<i>November</i>		—	1.7	—
	Early	—	—	—
	Middle	—	—	—
	Late	—	1.7	—
<i>December</i>		—	6.3	—
	Early	—	4.6	—
	Middle	—	—	—
	Late	—	1.7	—

¹⁾ Data provided by Dr. S. Tanaka of the Japanese Fisheries Agency.

* No data available.

at present, there is no method of identifying the various races of chinook salmon until such time as the adults arrive on a particular spawning ground.

There are few data describing the arrival of chinook salmon in Asian waters. Data supplied by Tanaka (Table 1) show that chinook are landed in Ozuchi, in northeastern Honshu, in small quantities from November through January; however, most are landed in the April–May–June period. The chinook caught in the November–January period are apparently immature, as indicated by a 10-day catch of 1.7 kg, which is a small weight even if it consisted of only one fish. An ocean migration and not a spawning migration is indicated for these fish. In describing Okhotsk Sea fisheries, Shmidt (1950) noted that chinook runs to the Soviet coast start in early May and continue to the end of August with no pronounced peak. The 1960 catch statistics of the Kamchatka Peninsula (Research Institute of Marine Fisheries and Oceanography of the U.S.S.R., 1961), show only 30 metric tons of chinook for West Kamchatka and 670 tons for East Kamchatka. The latter catches started in May and peaked in June with only one metric ton landed in August. Data are not available in sufficient detail to comment on the number of runs and races which may exist in the various Asian streams.

LIFE HISTORY IN FRESH WATER

The individual races found in various rivers and tributaries may have unique freshwater life histories and total life histories. While the literature establishes the existence of these differences, it does not broadly document them, nor describe them in detail.

It is apparent, for example, that the runs or races described by Fry (1961) spawn at different times. Some of the eggs, therefore, incubate in a falling temperature regime, while others incubate during rising temperatures. The time of hatching of eggs from these different races therefore differs, as well as the environmental and ecological conditions with which the resulting young must endure and cope. What

effects, if any, the differences in season of emergence of fry from the gravel would have on later migration and distribution in marine waters are conjectural and substantially unknown.

Differences of the type found in the Sacramento River system are also found elsewhere. Mains and Smith (1955) reported on concurrent sampling for downstream migrants on (1) the Snake River, (2) the Columbia River above the mouth of the Snake and (3) the Yakima River, which joins the Columbia above the mouth of the Snake but below the Columbia River sampling point. The Snake and Columbia Rivers in this area are migration routes for both spring and fall migrating races of chinook adults. Table 2 illustrates some of the differences found in the resulting downstream migrants. (Hereinafter, the word "fingerlings" will apply to chinook lacking a freshwater annulus, while "yearlings" will include those that show one freshwater annulus.) These three areas show a dominant downstream migration in the spring, although a few chinook are found occasionally in other months in the Snake and Yakima Rivers. These data from Mains and Smith (1955) show differences in size, time and age of migration at three concurrent sampling locations on the Columbia River and its tributaries.

The reports of the U.S Army Corps of Engineers (i.e., 1950) show that chinook salmon fingerlings and yearlings are present every month of the year in the Bonneville Dam area. In the Taku River in Alaska, however, most chinook salmon migrate to sea in the April–June period, with the peak occurring in May (Meehan and Siniff, 1962). Smoker (1954) reported that fall run chinook salmon in Puget Sound normally migrate to salt water after about 90 days in fresh water while the spring run progeny may remain in fresh water for more than one year.

Rutter (1903) reported catching seaward migrants in the Sacramento River at Walnut Grove from January into May. His trap caught at least some downstream migrants daily with maximum numbers

TABLE 2. Results of concurrent sampling for downstream migrating chinook salmon at three locations in the Columbia River watershed (from Mains and Smith, 1955).

River	Time of migration		Peak of migration		Age composition		Length in mm	
	Fingerling	Yearling	Fingerling	Yearling	Fingerling (%)	Yearling (%)	Fingerling (range)	Yearling (modal)
Snake	March–April	April–June	April	June	7–20	80–93	30–55	95–100
Columbia	March–April	June–July	April	June	76	24	20–55	85–90
Yakima		April–August		May	100			125

occurring in March. While some yolk-sac fry were taken, sizes generally ranged from about $1\frac{1}{2}$ inches (3.8 cm) at the start of the season to about three inches (7.6 cm) at the end. Gilbert (1913) reported that in Alaska as well as in the Sacramento River some chinook salmon pass to salt water in the spring and early summer while others remain in fresh water and go to sea as yearlings during their second spring. Hanson *et al.* (1940) found that a fall downstream migration occurred in some of the Sacramento River tributaries.

These examples have demonstrated that differences in growth and time of migration do occur among the juvenile chinook salmon from different races in a given river system and between races in different rivers. There are two additional features which may be characteristic of a watershed—(1) length of time in fresh water and (2) total age.

AGE AT MIGRATION

Clark (1929) stated that 80 to 90 percent of the Sacramento chinook salmon have scales of the ocean nucleus type (as defined by Gilbert, 1913) and that chinook returned to the Sacramento primarily (50 percent) as four-year-olds. They also returned as five-year-olds, three-year-olds, six-year-olds and two-year-olds, in that descending order of abundance. Fry² reports that this age composition is no longer true; the four-year-olds predominate in some years, three-year-olds in some years; two-year-olds are common, five-year-olds less so, and six-year-olds quite scarce.

Rich (1920) seined at various places in the lower Columbia (excluding hatcheries) and found 97 chinook salmon which he classified as yearlings and 473 as fingerlings. Hence, about 80 percent of his samples had ocean type scales. He stated that his data suggested that the fastest growing individuals left for salt water first. It should be noted that Mains and Smith (1955) found yearling migrants into August and peak migrations in June, while Rich (1920) discontinued sampling after May 25. Rich (1920) also concluded that males and females migrated out of the Columbia River in equal numbers throughout the seasons of migration.

Rich and Holmes (1929) reported that spring chinook returned to the Columbia River in their third to sixth years, with the greatest number maturing in their fifth year; the six-year-olds exceeded the four-

year-olds, with the three-year-olds being least common. For the fall chinook, the four-year-olds were apparently most abundant, with the five-year-olds second most abundant. Some two-year-old males and three-year-old females also occurred, but no six-year-olds were recorded. Van Hyning³ reports that, at present, four- and five-year-olds are most abundant in the Columbia River spring chinook with very few six-year-olds; three- and four-year-olds are most abundant in the fall chinook.

Samples of Taku River seaward migrant chinook salmon were all of the stream type, with 94 percent being in their second year and six percent in their third year at time of migration, according to Meehan and Siniff (1962). However, Parker *et al.* (1954) presented contrary data from reading adult scales showing that most had ocean type scales. Although the matter is under study⁴, it seems probable that the more recent work of Meehan and Siniff more accurately describes the true age composition, since it was done when scale reading methods were more advanced and on scales taken from small fish, not adults. Returning adults (Edson *et al.*, 1955) varied in age from two- to six-year-olds. Different levels of abundance for each yearclass of returning adults were indicated, depending on the sampling method—troll and gillnet catches being different from each other and both being different from catches of a fish wheel. In an estimated compilation by Edson *et al.* (1955), the five-year-olds were usually more abundant, followed by four-, three-, two- and six-year-olds, in that descending order.

In the Yukon River samples reported by Gilbert (1922), all were of the stream type. Two-year-old adults were absent and only one three-year-old was taken. All fish less than five years old were males. Six-year-olds of both sexes were more abundant than five-year-olds, seven-year-olds being the least common in the mixed-sex groups.

Throughout their North American range, then, chinook salmon may be expected to migrate to the sea over a rather wide range of time after hatching. At the southernmost point of their distribution, some may migrate as yolk-sac fry, although some may remain in fresh water for from a few months to a year. In the rivers farthest north, all may stay at least a

² Personal communication from D. H. Fry, Jr., to J. E. Mason, dated August 2, 1963.

³ Personal communication from Jack M. Van Hyning to J. E. Mason, dated Nov. 26, 1963.

⁴ Personal communication from Dr. William R. Meehan, Alaska Department of Fish and Game, to J. E. Mason, dated February 14, 1963.

year in fresh water. The age at maturity varied from one to six years in more southern areas, with four- and five-year-olds being more abundant. Farther to the north, the five- and six-year-olds were more abundant.

MIGRATIONS IN COASTAL WATERS

The preceding material has established that most downstream migrants enter salt water in the spring, as fingerlings and yearlings, at least in streams south of Alaska. Rich (1920) noted a tendency for the larger downstream migrants of a particular tributary to migrate earlier than the smaller. Rich and Holmes (1929) presented data to show that there were many gradations between typical stream and ocean types of scales, which are apparently related to the time and method of entry into brackish water and the duration of stay therein. Clark (1929) reached the same conclusions for the Sacramento River chinook salmon and Snyder (1922 and 1923) showed that departures from the typical scale types also occurred in Klamath River fish.

In the brackish and marine environment, almost nothing is known of growth, distribution and migration until the fish are of sufficient size to be taken in commercial troll or sport fisheries. Pressey (1953) shows that the size of first entry into the sport fishery of Puget Sound is at about 11 inches (27.9 cm) and about 15 inches (38.1 cm) in the Strait of Juan de Fuca area. Fraser (1917) reported immatures from the Departure Bay area of British Columbia a little in excess of 10 inches (25.4 cm) long. The Columbia River troll fishery takes chinook as small as 17 to 18 inches (43.2 to 45.7 cm) in length (Van Hying, 1951), although smaller chinook are caught but not landed. Neave (1951) reported on tagging in the troll fishery of the west coast of Vancouver Island. The age composition included chinook of the 2₁ age group and individuals below 24.5 inches (62.2 cm) in length and less than five pounds (2.3 kg) in weight. Immature chinook salmon were thus included, although the minimum size caught is not a matter of record.

All the Puget Sound-British Columbia and Columbia River samples were obtained from areas where chinook salmon populations from more than one river may be found. The only available data on the origin of these mixed populations is from marking experiments, as follows. The most northerly recoveries recorded by Rich and Holmes (1929), reporting on results of liberating marked chinook salmon at Columbia River hatcheries, were one spring run chinook from Dixon Entrance, southeastern Alaska, and two fall run chinook, one each from near Barkley Sound and near

Ucluelet (west coast of Vancouver Island). The Cowichan River chinook marked in the years 1937 to 1944 resulted in over 65 recoveries in the Georgia Strait area and along the west coast of Vancouver Island (Neave, 1941a, 1941b, 1949; Neave and Pritchard, 1942).

More recent Columbia River marking experiments, as reported in Pacific Marine Fisheries Commission (1959), have resulted in recoveries in Washington, Oregon, British Columbia and in southeastern Alaskan commercial fisheries. These experiments were not specifically designed for studies of ocean distribution and do not materially aid in the understanding of this distribution.

DISTRIBUTION INDICATED BY TAGGING IN SOUTHEASTERN ALASKA

On the basis of scale type, age composition and growth, Parker and Kirkness (1951) indicated that southeastern Alaskan chinook salmon are of two types, those found in inside waters and those found in outside coastal waters. Parker and Kirkness (1956) divided the latter into three groups by the characteristics of the chinook salmon found there. Those in the Cross Sound to Cape Fairweather area averaged about 27.5 inches (69.9 cm) in fork length. Most (probably in excess of 80 percent) were immature, with 4₁'s being most abundant, followed by 3₁'s. Chinook salmon found on the west coast of Chichagof Island were mostly (probably in excess of 80 percent) mature. Their modal fork length was between 30.0 inches (76.2 cm) and 32.5 inches (82.6 cm). Age group 4₁ was most abundant, followed by 5₁.

Since most recoveries (86.5 percent) of tags applied in outside waters were made outside of Alaska, Parker and Kirkness (1951, 1956) were of the opinion that the chinook salmon in outside waters were primarily from streams to the south of Alaska. Chinook salmon on the west coast of Prince of Wales Island were the largest of the three areas, with the principal modal fork length lying between 35.0 inches (88.9 cm) and 37.5 inches (95.3 cm). Again, probably in excess of 80 percent were mature, with the dominant age groups being 4₁ and 5₁, in that order. Rich and Ball (1933) reported that about 60 percent of the tags recovered from tagging off Baranof Island in 1926 and 1927 came from the Columbia River. Thus, two tagging experiments separated by many years resulted in substantial numbers of recoveries in fisheries to the south. In inside passage areas, all adult chinook tagged were of the ocean scale type as compared to 10-20 percent in outside waters. The 1951 tagging reported by Parker *et al.* (1952) resulted in no rec-

overies from tags applied north of Cross Sound, while those recovered from tagging south of Cross Sound supported the opinion of Parker and Kirkness (1951)—that chinook salmon in that area were primarily from streams to the south of Alaska.

The spring season tagging in inside passage waters such as Stephens Passage and Clarence Strait resulted in substantial numbers being recovered in Alaskan rivers when tagging was in close proximity to the rivers. When tagging was removed from such rivers or carried out later in the season, numbers were recovered in areas to the south and in British Columbia with only rare recoveries to the north and west of the tagging locations.

Kirkness *et al.* (1953) reported on tagging chinook salmon north of Cape Spencer in 1952. The returns followed the pattern for previous tagging in the area and also resulted in the first returns in an Alaskan river (the Taku) from Alaskan tagging. They concluded that the stocks of chinook salmon north of Cape Spencer were composed largely of immatures and that their origins were primarily from rivers to the south. Tagging in southeastern Alaska in 1951 and 1952 resulted in northern British Columbia recoveries, but none from the Fraser or Columbia Rivers.

DISTRIBUTION INDICATED BY TAGGING IN BRITISH COLUMBIA

Milne (1957) summarized chinook salmon tagging in British Columbia in the years 1925–1930 and compared the results to tagging in 1949–1952. He reported very little difference in total percentage of tags recovered between the two time periods. In both periods, the majority of the chinook salmon tagged in outside coastal waters travelled in a southeasterly direction toward the Fraser and Columbia Rivers. In recent years, more were recovered in British Columbia waters than in earlier years. He states that “Off the southwestern part of Vancouver Island many small immature fish are also captured while they are foraging in the ocean a year or two prior to the spawning migration.”

DISTRIBUTION INDICATED BY TAGGING IN WASHINGTON

Kauffman (1951) reported on tagging of chinook salmon in 1948 and 1949 at Swiftsure Bank and at Umatilla, recoveries from tagging in other areas being too few for conclusions. The Swiftsure tagging resulted in a rather high rate of recovery (55–62 percent of those recovered) in the general tagging area, and a substantial number of recoveries (26 out of a total of 58 recoveries from 1949 tagging) one or more

years after tagging. A high abundance of immatures in the tagging area was thus indicated. Recoveries also came from areas northwest of the tagging site to near the northern tip of Vancouver Island and from the Fraser and Columbia Rivers. The Umatilla tagging showed a movement of chinook to the Sacramento and Columbia River areas, Puget Sound and along the coast of Vancouver Island.

DISTRIBUTION INDICATED BY TAGGING IN OREGON

Van Hyning (1951) reported on tagging undersized chinook (less than the legal 27 inches, 68.6 cm) in 1948 and both undersized and larger chinook in 1949 on the coast of Oregon. Very few tags were applied at the three sites, the Columbia River, Newport and Coos Bay. Only five tags were recovered from the Columbia River tagging, none from Newport and six from Coos Bay. The recoveries indicated a northward movement from the Columbia River along the coast of Washington to the coast of British Columbia. Two of the five tags applied near the Columbia were recovered in the Columbia River and one in San Francisco Bay. Some of the tags from the Coos Bay tagging were recovered north and one was recovered south of the tagging location. In scale samples from Astoria and Newport taken in 1947, Van Hyning found that about 72 percent were of the ocean nucleus type compared to about 78 percent reported by Rich (1920) for this general area.

DISTRIBUTION INDICATED BY TAGGING IN CALIFORNIA

Fry and Hughes (1951) reported on California tagging of chinook in the years 1939 to 1942 and 1948 to 1949. The results showed that the Sacramento-San Joaquin River systems were the primary suppliers of chinook salmon to the California coastal troll fishery, although a few recoveries came from California streams north of the Sacramento. Point Arena seemed to be a dividing point. Most of those tagged south of this point were recovered to the south, while most of those tagged to the north were recovered to the north.

SUMMARY OF TAGGING

These various tagging experiments indicate that most chinook salmon yearling and fingerling migrants must move to the northward on entering marine waters. For the Columbia River chinook, this migration is most pronounced. However, a few chinook from many areas may travel to the south. Evidence from tagging has demonstrated that large numbers of chinook from the Columbia River and southern British Columbia river systems migrate into

the troll fishery areas of British Columbia and Alaska. Along the inside shores of southeastern Alaska, British Columbia and Puget Sound, there are apparently chinook salmon which do not migrate to any great extent in a northward direction. Present evidence indicates that some of the chinook in inside waters may not intermingle to any great extent with those of the outside coastal areas of Washington, British Columbia and some Alaskan waters.

CHINOOK SALMON STOCKS IN NORTH AMERICA AND ASIA

The numbers of chinook salmon caught in North America for the years 1920 through 1961 are summarized in Table 3. Similar statistics for Asia for the years 1909 through 1961 are presented in Table 4. These commercial fisheries data have generally been more complete and accurate in more recent years. While California, for example, adopted its basic "fish ticket" or multiple sales slip system in 1918, for many years all species of salmon were combined so that single species data are unavailable for the years 1920 through 1946. Oregon adopted a fish ticket system in 1923, and adoption of and improvements in this system followed in Washington in 1935 and in both British Columbia and Alaska in 1951.

Soviet and Japanese commercial catch statistics were unavailable for some years, even into the 1930's (Table 4). In general, however, the data were more detailed since World War II, and were later improved by the release of Japanese mothership data for $2^{\circ} \times 5^{\circ}$ statistical areas and ten-day periods. Tables 3 and 4 both show omissions in knowledge of commercial catch statistics. The figures which most accurately represent the catches of both continents are probably those following the close of World War II.

While the accuracy and detail of North American, Japanese and Soviet commercial catch data increased in recent years, a similar improvement in the recording of North American sport fisheries and other personal use catches was not apparent. The sport fisheries in ocean waters have grown tremendously in post World War II years and fishing effort in inshore and freshwater areas has also increased. However, none of the fishery agencies has developed a means of completely censusing the numbers of chinook landed in diverse fishing areas over protracted seasons by various types of non-commercial fishing gear. As a result, the sport catches shown in Table 3 are believed to be minimum figures in most cases.

In spite of these deficiencies, when the total chinook

landings of the two continents are compared, North American catches greatly exceed the combined catches by the U.S.S.R. and Japan (Figure 4). It is also apparent that in spite of substantial fluctuations in the North American catches since World War II, there has been an increasing trend in numbers of chinook caught. The combined Soviet and Japanese catches since 1952 have shown a general increase which is probably attributable to expansion of both the Soviet coastal and Japanese mothership fisheries. Figure 4 shows that since World War II the North American catch has tended to increase. Figure 5 shows that in this period the United States catches have tended to fall, while those for Canada have tended to rise. It should be noted that the sport catches are missing for some states for 1959, 1960 and 1961, which could influence the trends of the catches. However, the trends remain the same if Figure 5 is replotted with sport catches assumed to be the highest of record in each state for the missing years.

In recent years, the Japanese commercial catch has been taken primarily in offshore waters by gillnets and to some extent longlines. In coastal waters of both Japan and the U.S.S.R., both traps and nets are used. The North American catch is primarily taken by trollers operating in both open coastal and inside waters. A major exception is commercial fishing in Bristol Bay and its tributaries, which is exclusively by gillnet. In inside waters, gillnets take substantial numbers, particularly in river estuaries such as those of the Columbia and Fraser Rivers and places such as Cook Inlet in Alaska. In some areas, traps, dip nets and fish wheels still operate, most commonly for personal use fisheries.

The troll fisheries make appreciable catches starting in May, with catches substantially reduced after August. To illustrate the seasonal variation in catch between different North American areas, the percentiles of representative troll catches for the year 1960 were calculated (Table 5). It should be noted that these data were subject to the effects of variations in regulations, fishing effort, weather and market conditions.

DISTRIBUTION AND ABUNDANCE OF CHINOOK SALMON IN OFFSHORE WATERS

The offshore distribution and abundance of chinook salmon will be described from catches of research vessels using purse seines, gillnets and longlines, and from catches of the Japanese mothership fishery. The data to be used for these purposes were taken from

TABLE 3. North American catches of chinook salmon, in thousands of fish, with available data on sport catches given in parentheses.

Year	Alaska ¹⁾	British Columbia ²⁾	Washington ³⁾	Oregon ⁴⁾	California ⁵⁾	Total
1920	775.5	641.8	771.4	—		2,188.7
1921	826.4	406.8	598.7	—		1,831.9
1922	770.3	373.2	562.9	843.3		2,549.7
1923	681.4	343.0	678.2	1,157.4		2,860.0
1924	794.3	305.8	1,267.5	1,307.0		3,674.6
1925	816.6	666.5	1,219.2	1,428.0		4,130.3
1926	588.6	489.9	980.7	1,093.2		3,152.4
1927	967.3	614.3	1,090.0	1,142.1		3,813.7
1928	656.6	415.0	894.7	800.3		2,766.6
1929	768.1	344.8	972.9	729.6		2,815.4
1930	892.9	539.4	1,025.1	791.0		3,248.4
1931	680.3	424.7	1,042.6	926.5		3,074.1
1932	882.3	645.6	910.2	710.6		3,148.7
1933	608.7	448.2	894.0	874.9		2,825.8
1934	559.7	1,737.3	872.5	807.3		3,976.8
1935	800.5	1,341.4	563.1	821.0		3,526.0
1936	894.1	1,634.4	610.3	968.1		4,106.9
1937	1,071.8	813.8	652.4	1,070.5		3,608.5
1938	927.7	330.7	434.7(27.5)	735.9		2,456.5
1939	817.6	361.0	468.5(34.8)	754.0		2,435.9
1940	574.2	326.3	588.1(34.1)	807.6		2,330.3
1941	1,126.2	713.3	656.8(29.8)	1,026.6		3,552.7
1942	739.8	415.7	607.7(8.3)	940.2		2,711.7
1943	629.6	1,076.4	487.0	623.2		2,816.2
1944	506.2	276.4	497.2	751.5		2,031.3
1945	608.2	502.1	546.1	779.2		2,435.6
1946	739.9	780.5	643.4(23.4)	866.3		3,053.5
1947	717.8	874.3	637.2(12.8)	1,004.6	759(5)	4,010.7
1948	677.9	513.9	572.8(12.0)	927.4	517(11)	3,232.0
1949	703.8	*	507.8(105.2)	632.9(8.0)	438(23)	2,418.7**
1950	609.9	*	480.4(114.6)	567.9(11.0)	487(57)	2,327.8**
1951	789.5	794.0	594.8(139.2)	620.7(10.0)	476(103)	3,527.2
1952	735.3	905.4	662.1(213.0)	519.0(11.0)	512(123)	3,680.8
1953	713.0	1,013.9(75)	630.4(152.2)	445.0(15.0)	533(141)	3,718.5
1954	610.4	876.8(76)	570.1(219.1)	428.7(17.0)	828(171)	3,797.1
1955	582.1	872.0(90)	651.2(228.9)	627.7(59.0)	868(184)	4,162.9
1956	458.0	983.1(106)	519.3(318.6)	677.8(51.0)	1,026(163)	4,302.8
1957	513.8	938.1(135)	586.2(331.9)	461.5(79.0)	491(64)	3,600.5
1958	550.2	1,068.7(144)	481.6(235.1)	398.8(74.0)	375(65)	3,392.4
1959	601.2	948.3(117)	375.0(197.0)	247.2	514	2,999.7
1960	547.2	742.5(93)	288.3(195.2)	338.3	540	2,744.5
1961	503.6	685.3(67)	371.1(205.6)	297.5	792	2,922.1

* No data available in number of fish for B.C. catches in 1949 and 1950.

** Incomplete total.

¹⁾ From Kasahara (1963), Table 47.

²⁾ From Kasahara (1963), Table 60 (commercial) and Table 80 (sport). Sport catches include 25% of "grilse" catches as given by Kasahara.

³⁾ From 1920 to 1934, from Kasahara (1963), using 19.48 lbs per fish. From 1935 to 1961, from 1962 Annual Report, Washington State Department of Fisheries, except that sport catches given for 1938 to 1942 are from Annual Bulletins 38, 39, 40, 41 and 42 of the Washington State Department of Fisheries.

⁴⁾ For 1922 to 1955, Oregon commercial catches in Table 69 of Kasahara (1963) were converted from metric tons to pounds (2,204.59 lbs per metric ton) and then to number of fish (15 lbs per fish—see Kasahara's note 7, Table 75); for 1956 to 1961, data were taken from INPFC Statistical Yearbooks. Sport catches from 1949 to 1958 are from Kasahara (1963), Table 82.

⁵⁾ For the years prior 1947, there are no data available on catches of chinook salmon, since catches of coho and chinook were not separated. Commercial catches shown here are from D. H. Fry, Jr., California Department of Fish and Game, as given in a letter to J. E. Mason dated August 2, 1963. Sport catches for 1947 to 1958 are from Kasahara (1963), Table 82.

TABLE 4. Commercial catch of chinook salmon, in thousands of fish, by Japanese and U.S.S.R. fisheries.

Year	Catch by Japan from U.S.S.R. coast ¹⁾	U.S.S.R. coastal catch ²⁾	Japanese mothership and North Kuril fisheries ³⁾	Total
1909		2.6		2.6
1910		0.4		0.4
1911	6.0	8.2		14.2
1912	5.1	25.4		30.5
1913	28.2	7.3		35.5
1914	11.8	8.7		20.5
1915	17.6	10.1		27.7
1916	15.0	8.8		23.8
1917	14.9	24.4		39.3
1918	12.0	79.4		91.4
1919	50.6	0.8		51.4
1920	70.3	6.5		76.8
1921	64.6			64.6**
1922	35.8	39.0		74.8
1923	24.8			24.8**
1924	23.7			23.7**
1925	39.6			39.6**
1926	77.0			77.0**
1927	98.2	7.8		106.0
1928	68.6	18.4		87.0
1929	82.5	26.5		109.0
1930	111.6	67.4	3.3	182.3
1931	74.8	40.2	4.7	119.7
1932	74.8	53.2	2.8	130.8
1933	35.5	15.5	1.1	52.1
1934	68.7	23.3	3.2	95.2
1935	103.2	40.8	20.3	164.3
1936	77.0	65.0	41.4	183.4
1937	123.4		32.6	156.0**
1938	91.4		28.8	120.2**
1939	57.6		9.1	66.7**
1940	67.3	22.0	12.0	101.3
1941	66.3	57.0	13.4	136.7
1942	31.4	36.0	16.0	73.4
1943	*	48.0	4.5	52.8
1944	*	17.0	*	17.2
1945		38.0	*	38.0
1946		81.0		81.0
1947		81.0		81.0
1948		130.0		130.0
1949		75.0		75.0
1950		62.0		62.0
1951		72.0		72.0
1952		66.0	1.0	67.0
1953		88.0	8.0	96.0
1954		65.0	74.0	139.0
1955		134.0	76.0	210.0
1956		110.0	137.0	247.0

Continued.

TABLE 4. (Continued)

Year	Catch by Japan from U.S.S.R. coast ¹⁾	U.S.S.R. coastal catch ²⁾	Japanese mothership and North Kuril fisheries ³⁾	Total
1957		90.0	31.0	121.0
1958		70.0	46.0	116.0
1959		98.3	68.0	166.3
1960		70.0	180.0	250.0
1961		65.0	31.0	96.0

* Less than 500 fish.

** Incomplete total.

¹⁾ From Kasahara (1963), Table 15.

²⁾ For 1909 and 1910, from Baievsky (1926). For 1911 to 1922, by subtraction of Kasahara's Japanese catch from total U.S.S.R. coastal catches given by Baievsky (1926); for 1927 to 1936, by subtraction of Japanese catch from total U.S.S.R. coastal catch, both as given in Kasahara (1963); for 1940 to 1961, from metric ton figures given by Kasahara (1963) in Table 29, converted to number of fish using a conversion factor of 22 lbs per fish approximated from 1958 through 1961 averages given in Table 32 of Kasahara (1963).

³⁾ For 1930 to 1945, from Kasahara (1963), Tables 34 and 35; for 1952 to 1961, from Kasahara's Table 37 (mothership catches only).

the annual reports of the International North Pacific Fisheries Commission (1955-1961), INPFC Statistical Yearbooks for 1952 through 1961, Neave *et al.* (1962), French (1964), Powell and Peterson (1957) and Fisheries Agency of Japan (1962). Before proceeding, some of the limitations and possible sources of error in the data should be recognized.

LIMITATIONS OF THE DATA

The research vessels of Canada, Japan and the United States have used a variety of gear in the period 1955 through 1962, including troll lines, purse seines, longlines and gillnets. Data from trolling were too few to be of any help in describing distribution and abundance, but appreciable numbers of chinook salmon have been taken in purse seines. However, since purse seines were usually operated in the more coastal waters and principally for the purpose of obtaining salmon for tagging, the resulting data are of limited use in describing offshore distribution of chinook. The same criticism can be made of some of the longline experimental fishing, although Canadian and Japanese longline fishing in 1962 was carried out in a manner which adds to knowledge of distribution and abundance.

The most consistent data are those procured from the use of gillnets fished in surface waters. Those fished

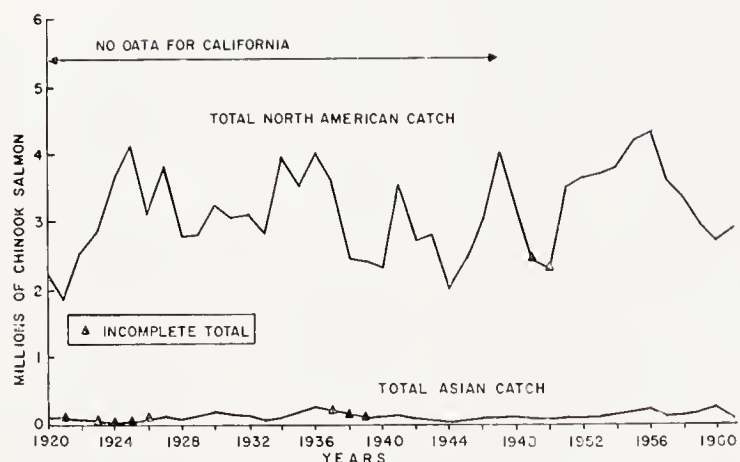


FIGURE 4. Chinook salmon catches (in millions of fish) from North America and Asia (U.S.S.R. and Japan), 1920–1960. Data from Tables 3 and 4.

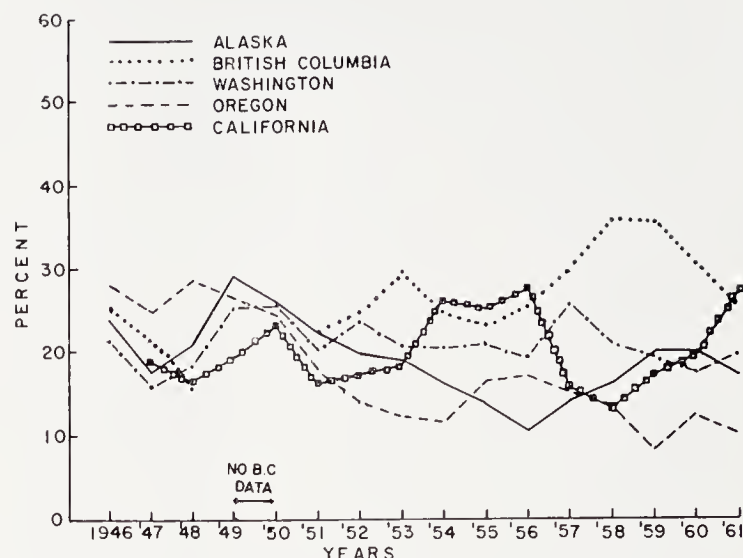


FIGURE 5. Chinook salmon catches in North America, by area, as percentages of total North American catch. Data from Table 3.

TABLE 5. Percentiles of chinook salmon troll catches by areas in 1960¹⁾.

Area	10%	25%	50%	75%	90%
<i>Alaska</i>					
Icy Strait and Western	May 21	June 4	June 18	July 16	Aug. 20
<i>British Columbia</i>					
Areas 1 and 2	May 28	June 18	July 9	July 23	July 30
Areas 22–27 and C	May 14	June 11	July 30	Aug. 13	Sept. 10
<i>Columbia River</i>					
Oregon Coastal	May 28	July 2	Aug. 6	Aug. 20	Sept. 17
<i>California</i>					
San Francisco	Early May	Early June	June	July	Mid-August

¹⁾ Data taken from INPFC Statistical Yearbook for 1960.

at depths in studies of vertical distribution, again, are of no material value in describing offshore distribution and have been omitted. The gillnets were typically of the INPFC standard meshes, that is, $5\frac{1}{4}$ ", $4\frac{1}{2}$ ", $3\frac{1}{4}$ ", and $2\frac{1}{2}$ " stretched mesh (13.3, 11.4, 8.3, 6.4 cm), although many other mesh sizes and both monofilament and multifilament synthetic web materials have been used, all in various amounts and in various combinations.

Since gillnets were used by all three nations for extended periods of time over broad ocean areas, it would appear desirable to describe distribution and abundance in terms of catch per unit of effort. Examination of the data revealed that the combined chinook catches by research vessels of Canada, Japan and the United States in the years 1955 through 1962 totalled less than 2,000 chinook for both surface fishing gillnets and the longline data which could be used to describe offshore distribution. The number of chinook salmon

caught was almost insignificant in terms of catch in numbers and in catch per unit of gear. The maximum figures given by Manzer *et al.* (MS 1963) for the Japanese landbased fishery by 10-day periods in the years 1956 through 1960 are 1.17, 0.22 and 0.16 chinook per tan (about 180 feet). All other catches amounted to only a few hundredths of a chinook per tan. In the Japanese mothership fishery, the maximum recorded catches per tan by months and areas were 0.23 and 0.09 chinook per tan, with most figures falling below 0.03 chinook per tan (INPFC Statistical Yearbooks 1954 through 1960). If the data for research vessels, the landbased fishery, or the mothership fishery were to be further divided to express catch per unit by mesh size, they would have even less significance. Since the total number of chinook caught was so small and since such a variety of gillnets was used, it was decided to avoid expressing results in terms of catch per unit of fishing gear. The data are expressed in terms of fishing position, numbers of occasions fishing was

carried out at that position and the number of chinook caught. This approximates catch per unit in terms of catch per set.

The approximate total of 2,000 chinook caught over eight years of fishing is a number of such small magnitude that it makes it impossible to compare abundance on a monthly basis or to compare catches by years. As a result, the seasonal changes discussed below for research vessel catches are based on combined data by months for 1955 through 1962. This totally obscures differences in abundance by years or seasonal variation which may be related to differences in ocean environment.

While research vessel fishing is intended to give unbiased estimates of salmon populations at each fishing location, the sampling gear is known to be selective. These vessels have usually fished surface waters and while the gillnet mesh sizes have generally ranged from 2½ to 5¼ inches (6.4 to 13.3 cm), the most efficient sizes for retaining larger and smaller chinook were not used. The bias due to this factor cannot be evaluated. Biases are also introduced from the use of longline gear, hook sizes and bait type both being recognized as introducing size and species selection. Here again the degree of bias is unknown.

The species identification of catches by research vessels are subject to correction after laboratory examination of specimens, such correction occurring on some occasions after the annual reports of the International North Pacific Fisheries Commission had been published. While there are occasions of misidentification of species or errors in recording data, they are relatively few, and this type of error should not significantly affect the analyses to follow.

Another factor limiting the analyses is the relative

lack of any numbers of chinook, not only in research vessel catches as was pointed out, but in the mothership fisheries, as shown in Table 6 for operations in 1957, which year was selected at random for demonstration purposes. The number of chinook is virtually insignificant in terms of catch in numbers and catch per unit of gear as compared to other species.

Other sources of bias in the commercial fishing data are selective fishing by area, by gear and by time for other species which may be more abundant or otherwise preferred. Therefore, catch, or catch per unit of effort, data of commercial gear cannot be used as unbiased indices of the distribution and abundance of chinook salmon. Unfortunately, it is not possible to estimate the degree of bias introduced by selective fishing.

There are other sources of error which may act in combination with the above. Table 7 compares catches by Japanese research vessels and motherships for specific times and areas. The table includes sockeye, chum, pink and coho salmon for illustration purposes, since so few chinook were taken. It can be seen that in 1957 the catches per tan by species for two research vessels were of the same general order of magnitude. However, the catch per tan of the 1957 mothership fishery was higher than that of the research vessels for some species (sockeye and pink) and lower for others (chum and coho). In 1958 and 1959, the mothership catches per tan were usually higher than those of the research vessels for all species (approximately two to four times). In 1960, however, mothership catches were lower than research vessel catches for all species except sockeye. These variations may be partly explained on the basis of (1) grossly dissimilar amounts of effort by the two fisheries, (2) the few occasions when both fisheries were operated concur-

Table 6. Catch and catch per unit of effort in 1957 for salmon caught in gillnets by Japanese and Canadian research vessels and the Japanese mothership fishery¹⁾.

Operation	Species				
	Sockeye	Chum	Pink	Coho	Chinook
<i>Japanese research vessels (2,203 tans)</i>					
Number of fish	4,297	3,004	5,516	516	7
Mean catch per tan	1.9	1.4	2.5	0.2	0.003
<i>Canadian research vessels (2,096 shackles)</i>					
Number of fish	998	1,797	519	355	5
Mean catch per shackle	0.5	0.9	0.2	0.2	0.002
<i>Japanese motherships (6,619,089 tans)</i>					
Number of fish	19,822,540	9,246,132	21,045,585	339,623	31,104
Mean catch per tan	3.0	1.4	0.32	0.05	0.005

¹⁾ Data from INPFC Annual Report 1957.

TABLE 7. Catch and catch per unit of effort by species of salmon for Japanese research and mothership vessels using the same types of gear in the same areas in the same time periods in the years 1957 through 1960¹⁾.

Year	Vessel	Date	Area ²⁾	Sockeye	Chum	Pink	Coho	Chinook	Tans
1957	<i>Kano-maru</i>	July 19-30	E6050, E6052	450	665	272	57	2	274
			Catch per tan	1.6	2.43	1.06	0.21	0.007	
1957	<i>Etsuzan-maru</i>	July 15-30	E6050, E6052	570	542	733	229	1	392
			Catch per tan	1.45	1.38	1.87	0.58	0.003	
		July 19-30	E6050, E6052	374	427	417	227	—	280
			Catch per tan	1.34	1.53	1.49	0.81		
1957	Mothership	July	E6050, E6052	2,301,830	665,063	5,382,496	111,628	4,766	959,152
			Catch per tan	2.4	0.69	5.6	0.12	0.005	
1958	<i>Kano-maru</i>	June 1-30	E6052, E6054	98	90	13	—	—	144
			Catch per tan	0.68	0.62	0.09			
1958	Mothership	June	E6052, E6054	224,811	262,557	234,710	68	1,423	182,879
			Catch per tan	1.23	1.44	1.28	0.0003	0.008	
1959	<i>Wakashio-maru</i>	June 10-20	E6048, E6052	215	230	193	1	—	260
			Catch per tan	0.83	0.89	0.74	0.004		
1959	Mothership	June	E6048, E6052	345,255	985,062	1,179,532	1,171	725	378,600
			Catch per tan	0.91	2.6	3.1	0.003	0.002	
1960	<i>Etsuzan-maru</i>	Aug. 10	E6552	55	36	1	34	—	60
			Catch per tan	0.92	0.6	0.02	0.57		
1960	Mothership	Aug. 1-10	E6552	26,703	2,036	41	171	—	8,448
			Catch per tan	3.16	0.24	0.005	0.02		

¹⁾ Data from INPFC Annual Reports, 1957, 1958, 1959 and 1960.

²⁾ See Figure 6.

rently, (3) commercial fishery statistics (except 1960) being tabulated by months whereas the research vessel catches were by specific days, and (4) the fact that the mothership fishing areas had boundaries as large as two degrees of latitude and five degrees of longitude. These various possible sources of error for sockeye, chum and pink salmon are assumed to apply as well to chinook salmon.

It is thus apparent that neither the research vessel nor mothership data for chinook salmon can be accepted as being superior. In most cases, the differences in data from the two sources may be viewed as being due, perhaps, more to sampling differences than to biological phenomena. As a result, trends or conclusions can be indicated only very generally.

The following material concerning distribution and abundance is based on chinook salmon catches in surface waters. If these fish occur in surface waters only occasionally or only seasonally, then the actual distribution of most of the chinook may be grossly different from any conclusions reached here.

DISTRIBUTION AND ABUNDANCE DESCRIBED FROM RESEARCH VESSELS USING PURSE SEINES

The purse seine catch data given by Hartt (1962) are summarized in Table 8 by INPFC statistical

area (Figure 6), month, catch per set, number of sets and for sets open to the east and west. While Hartt did not give specific information on maturity, he stated the opinion that most of the chinook salmon caught were immature, hence the following material is thought to apply primarily to immature chinook. The totals in Table 8 show a slightly higher average catch per set for sets open to the east than to the west, suggesting a possible westerly migration. A change in abundance in relation to time is also suggested for sets open to the east, as well as a substantial increase in abundance after the month of May. Such changes are not apparent in sets open to the west, due, at least in part, to the small number of sets and small catches of chinook in May, July and August.

Data for the areas in which chinook were caught in three or more consecutive months are summarized in greater detail in Table 9. Only areas E7052, E7550, 8050 and W7052, involving sets open to the east, met the three month criterion. While areas E7052 and E7550 in Table 8 show an increasing abundance of chinook in succeeding months, Table 9 shows that the changes were the result of combining data and were not actually time related. In Table 8, area W7052 shows an increased abundance in July as compared to June, but in Table 9 it is apparent only for 1957 and includes a total of only nine sets. The 1958 data

TABLE 8. Chinook catch per purse seine set for the combined years 1956 through 1958. Numbers in parentheses are total numbers of sets¹⁾.

Area code number	Open to East					Open to West				
	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.
E6554			0 (1)							
E7050	0.3 (3)	0 (1)	0.8 (14)			0 (0)		0.5 (2)		
E7052	0 (3)	0.07 (14)	0.3 (35)	0.5 (21)		0 (2)	0 (24)	0 (1)	0 (4)	
E7054		1.3 (3)	0 (2)			0 (1)	0.7 (3)	0 (1)		
E7548			0.5 (2)					0 (1)		
E7550	0 (1)	0.6 (5)	0.25 (4)	0.45 (13)			0 (3)	0 (3)	0 (6)	
E7552	0 (1)	0 (1)	1 (1)	0 (2)		2.5 (2)	0 (1)	0 (1)	1 (1)	
E7554			0 (1)					0 (1)		
8048			2 (1)					0 (1)		
8050	0 (2)	0.17 (23)	1 (60)	0.70 (44)		0 (4)	0 (1)	0 (3)	0 (1)	
8052	0 (1)	0 (1)	0.17 (6)			0.2 (5)	1 (3)	0 (2)		
8054		2 (2)	1 (1)				2.7 (3)	0 (1)		
8056		1 (1)					0 (1)			
W7550	0 (1)	0 (3)	0.6 (5)	2.3 (3)			0 (3)	0 (1)		
W7552		0.3 (1)	0 (2)				0 (1)			
W7556		4 (2)					0.3 (10)			
W7558							0 (1)			
W7560							0 (1)			
W7052		0.2 (35)	12 (8)	1.5 (4)			0.3 (6)	0.5 (4)		
W7054		0.25 (4)					0.4 (10)			
W7056							0.14 (14)			
W6552	0 (6)					0.3 (3)				
W6554		0.07 (15)	0 (2)							
W6050				0 (1)					0 (1)	
W6052				0 (4)						
W6054			0 (2)	1 (7)	1.5 (2)			0 (1)	2 (2)	
W5554		0 (6)		1.5 (8)	0 (2)		0 (1)	0 (2)	0 (1)	

Continued

TABLE 8. (Continued)

Area code number	Open to East					Open to West				
	May	June	July	Aug.	Sept.	May	June	July	Aug.	Sept.
W5556				0.2 (5)	1 (2)				5 (1)	
W5558										4 (1)
W5054		0 (1)								
W5056				0 (1)	0 (3)					0.5 (2)
W4554						0 (1)				
W4556					0 (1)					0 (3)
W4054										0 (1)
W4056					2 (2)					4.3 (3)
W4058										0 (1)
W3554					0 (2)					0 (2)
W3048										2.2 (13)
W3050					2.3 (3)					
Total chinook caught	1	37	188	80	16	7	24	3	10	46
Total sets	18	118	147	113	17	18	86	25	17	26
Catch per set	0.05	0.31	1.28	0.71	0.94	0.39	0.28	0.12	0.59	1.8
Total chinook caught: 322					Total chinook caught: 90					
Total sets: 413					Total sets: 172					
Catch per set: 0.77					Catch per set: 0.52					

¹⁾ Data from Hartt (1962).

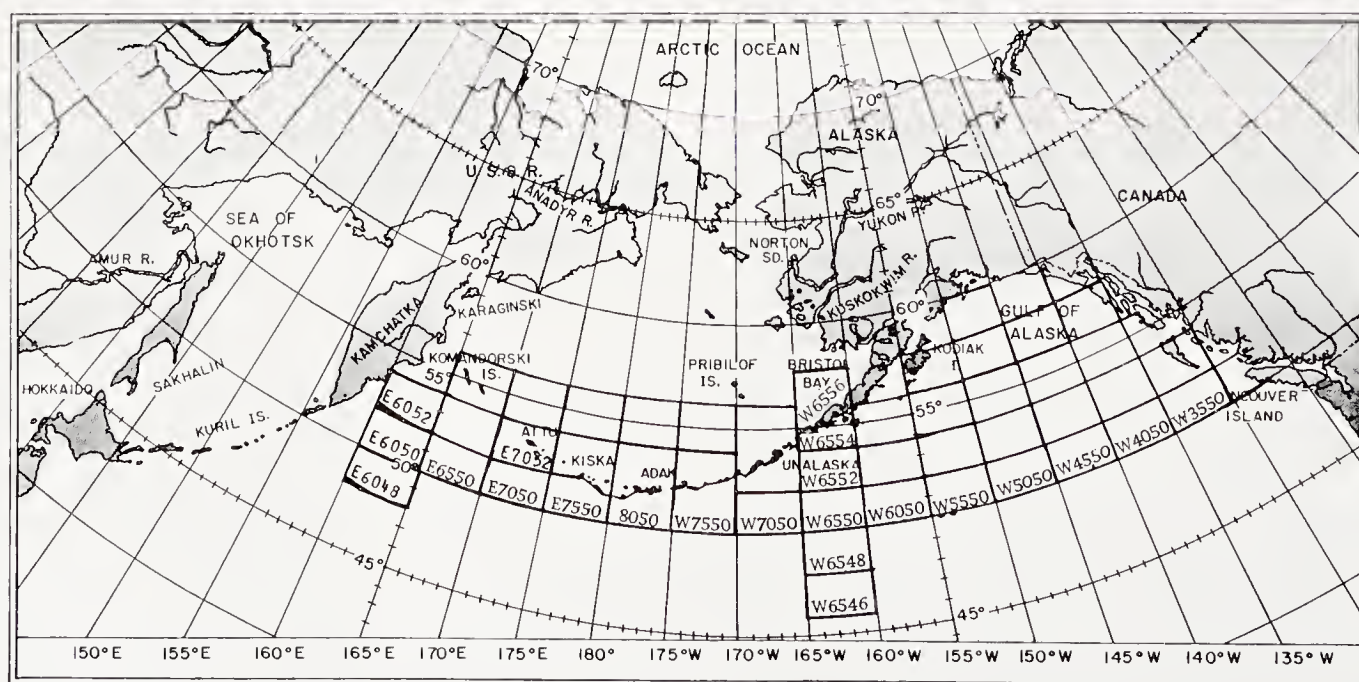


FIGURE 6. Reference map with key to area coding.

TABLE 9. Chinook catch per purse seine set for sets open to the east. Numbers in parentheses are numbers of sets¹⁾.

Year and area	May	June	July	August
1956 E7052	(0)	(0)	(0)	(0)
E7550	(0)	(0)	(0)	(0)
8050	(0)	0.11 (9)	0.06 (17)	0.78 (18)
W7052	(0)	0.19 (31)	(0)	5.0 (1)
1957 E7052	(0)	0 (4)	0.06 (17)	0.65 (17)
E7550	(0)	1.00 (3)	0.25 (4)	0.50 (12)
8050	0 (1)	0.20 (5)	1.55 (29)	0.69 (13)
W7052	(0)	0.25 (4)	1.60 (5)	0 (1)
1958 E7052	0 (3)	0.10 (10)	0.56 (18)	0 (4)
E7550	0 (1)	0 (2)	(0)	0 (1)
8050	(0)	0.22 (9)	1.00 (14)	0.62 (13)
W7052	(0)	(0)	29.33 (3)	0.5 (2)

¹⁾ Data from Hartt (1962).

were unusual in that the three sets made on July 2, 3 and 4 resulted in individual catches of 47, 27 and 14 chinook salmon on successive days. In Table 8, area 8050 shows increases in abundance of chinook in June and July, with a decline in August. Table 9 shows this same trend for area 8050 in 1957 and 1958; however, in 1956, the catch per set was lowest in July and highest in August.

The suggested westerly migration of chinook salmon indicates a possibility that they would become more abundant in the more western areas later in the season. This seems apparent in Table 9 for the 1957 data, which are more extensive than for 1956 or 1958.

The generally higher catches per purse seine set for sets open to the east as compared to the west suggest a westerly movement of chinook in areas

W7550, 8050, E7550 and E7052, adjacent to and south of the Aleutian Islands. While a total of only five sets was made in May in these four areas in 1956 through 1958, the data indicate that chinook were more abundant in June than in May. Catches in area 8050 for 1957 and 1958 indicate peak abundance in July and a decline in August, changes not clearly apparent in 1956 or in other areas. The 1957 data suggest that chinook become more abundant in the more western areas in August, possibly as a result of a migration to the west suggested by the differences between catches of purse seines set open to the east and open to the west. The successive catches of 47, 27 and 14 chinook per set in area W7052 in 1958 show that chinook may be found in concentrations in some areas and times.

DISTRIBUTION AND ABUNDANCE DESCRIBED FROM RESEARCH VESSELS USING GILLNETS

Figures 7 through 13 show summaries by months of positions and catches of chinook salmon by research vessels using surface fishing gillnets in the years 1955 through 1962. Each open circle shows a set location with no chinook catch. If more than one set was made, the number is shown in the upper part of or at the left of each circle. If one or more chinook was caught, the number is given below or to the right in each circle.

In offshore Pacific Ocean waters, the Okhotsk Sea and the Bering Sea, chinook were taken over nineteen degrees of latitude, from 41°N latitude (Figure 7) to 60°N (Figures 8 and 10) and across the entire Pacific from North America into the Okhotsk Sea close to the eastern shore of Sakhalin Island. It is apparent, however, that the distribution was not uniform and that

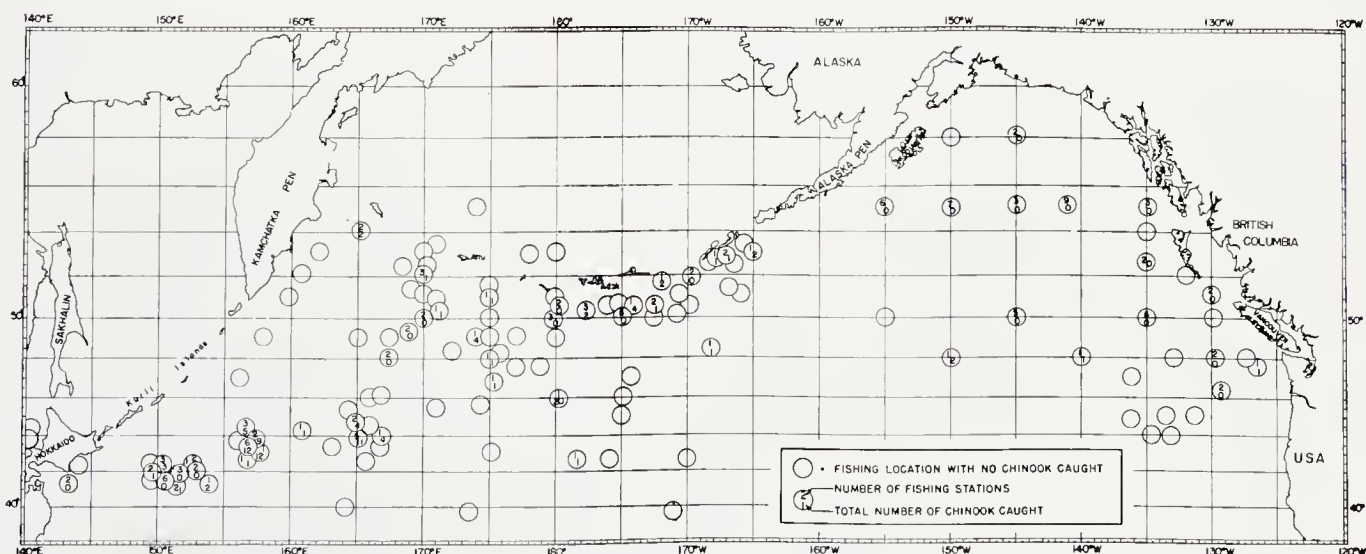


FIGURE 7. Gillnet fishing locations by research vessels of Canada, Japan and the United States in May, 1955 through 1962 combined.

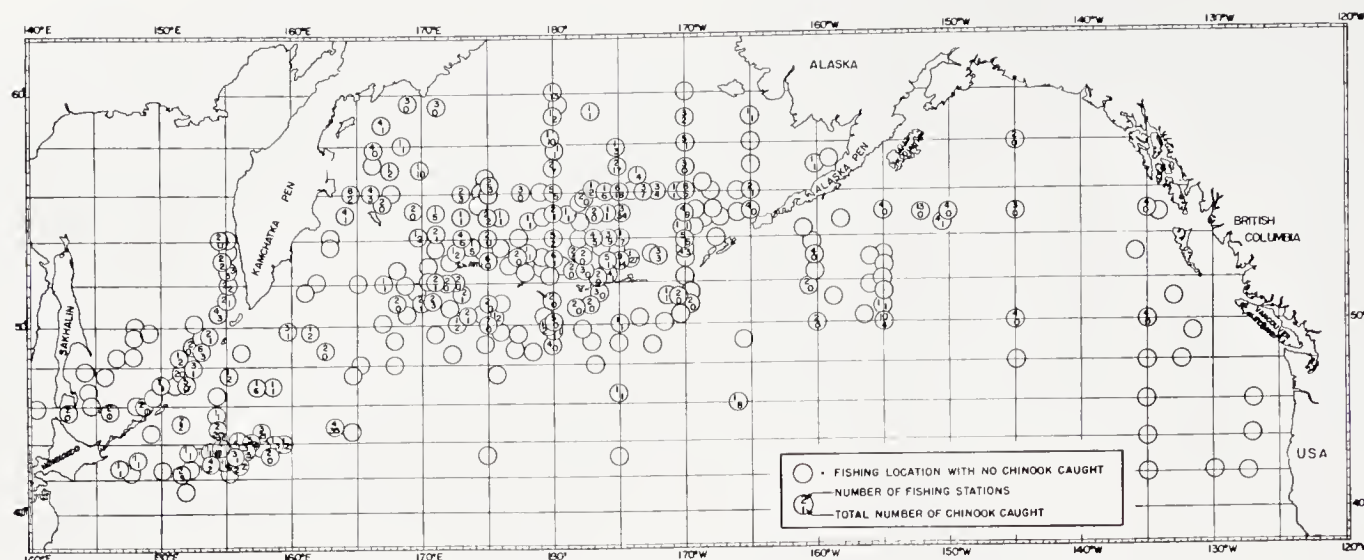


FIGURE 8. Gillnet fishing locations by research vessels of Canada, Japan and the United States in *June*, 1955 through 1962 combined.

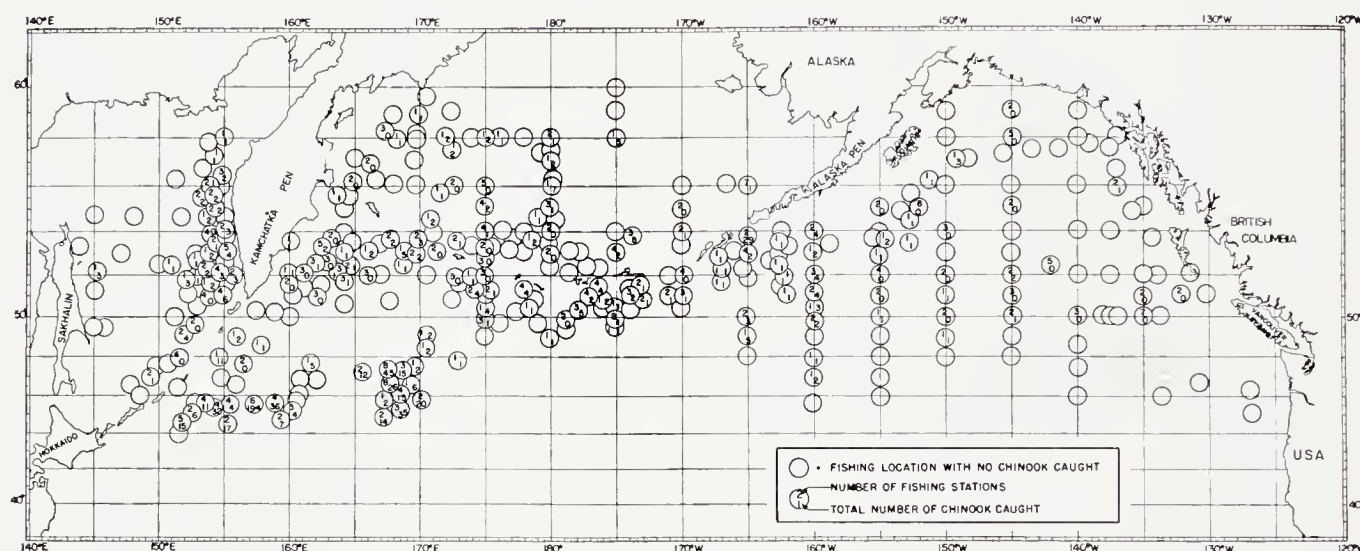


FIGURE 9. Gillnet fishing locations by research vessels of Canada, Japan and the United States in *July*, 1955 through 1962 combined.

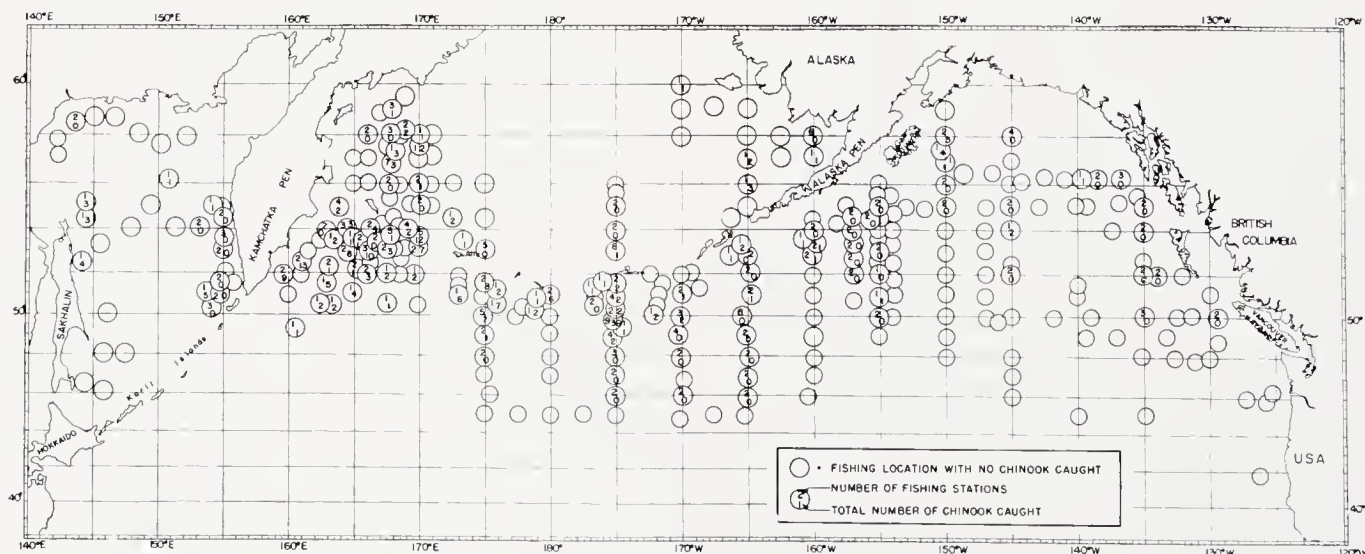


FIGURE 10. Gillnet fishing locations by research vessels of Canada, Japan and the United States in *August*, 1955 through 1962 combined.

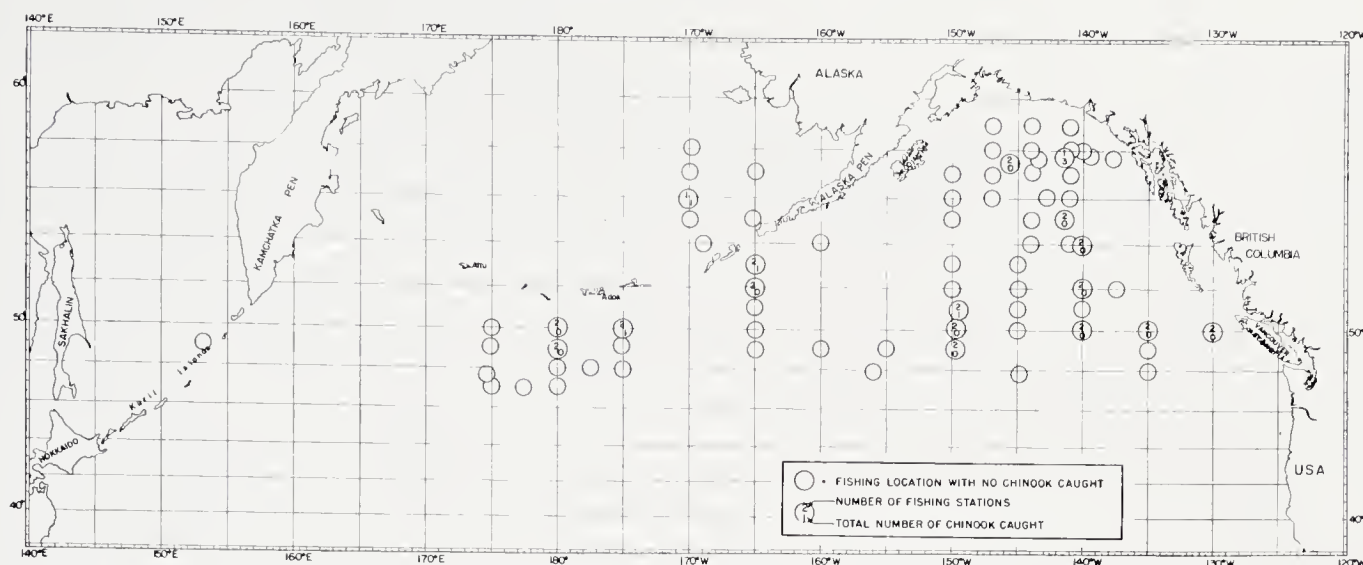


FIGURE 11. Gillnet fishing locations by research vessels of Canada, Japan and the United States in September, 1955 through 1962 combined.

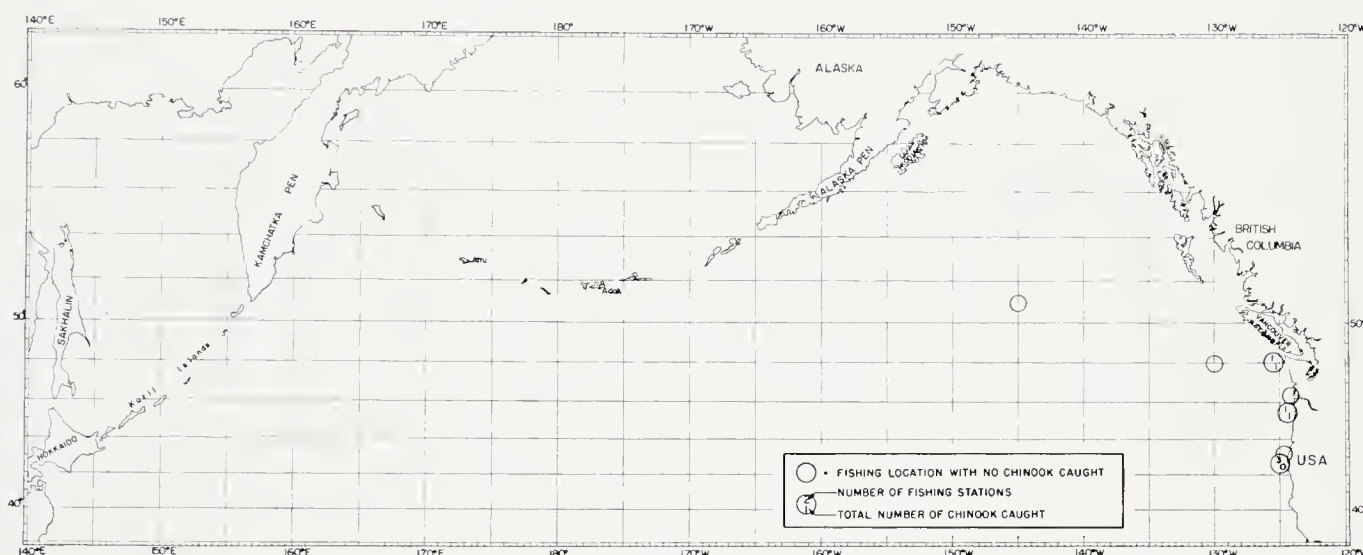


FIGURE 12. Gillnet fishing locations by research vessels of Canada, Japan and the United States in October, 1955 through 1962 combined.

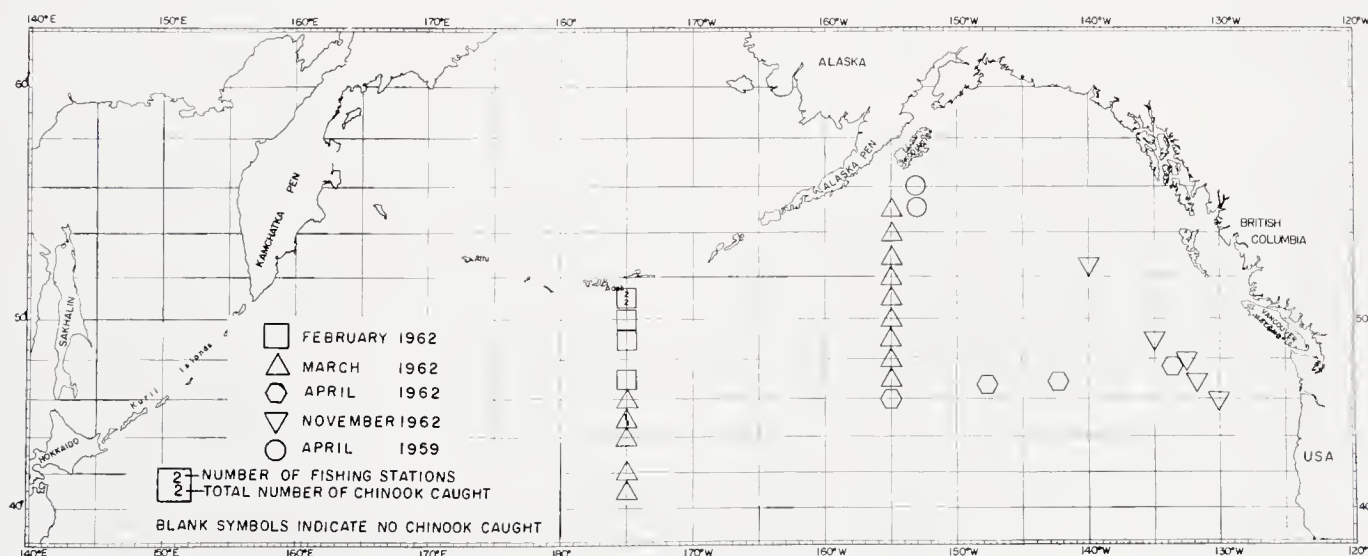


FIGURE 13. Gillnet fishing locations by research vessels of Canada, Japan and the United States in February, March, April and November, 1955 through 1962 combined.

the abundance of chinook varied during the spring and summer months at least.

Figure 13 summarizes gillnet fishing positions in the years 1955 through 1962 in all months other than May through October. All that can be said is that chinook may be found south of Adak in February and March.

Bering Sea

In the Bering Sea, data are too few for comment for periods earlier than the month of June (Figure 8). In June, chinook salmon were found from Bristol Bay to the Kamchatka Peninsula, northward from the Aleutian Islands to 60°N. They were apparently more abundant to the east of the 180° meridian than in waters to the west of 180°. Chinook were less abundant in July and August (Figures 9 and 10) in the central Bering Sea with the center of abundance located to the west of 180°. There may have been a similar movement east of 180°, but the data are too few for comment.

North Pacific Ocean

Gulf of Alaska to Unimak Island. No chinook salmon were caught in the area from the Gulf of Alaska to Unimak Island in May (Figure 7) except near the southern limit of fishing. They were caught in the southwest section of the area in June (Figure 8) and more to the north and northeast into the center of the Gulf in July (Figure 9). In both August and September, they were virtually absent from the center of the Gulf.

In July and August, chinook were relatively abundant west of Kodiak compared to east of Kodiak. This suggests that the Kodiak to Unimak area might be an area of transition between the Gulf of Alaska area and western areas. It is also apparent that chinook were virtually absent in a band or corridor running southeast from the Kenai Peninsula to the State of Oregon coast.

Unimak Island to Attu Island. In May, chinook were rather widely and sparsely scattered throughout the Unimak to Attu Island area south of the Aleutians. The few that were taken were generally rather close to the Aleutian Chain and in the westerly section of the area. In June (Figure 8), chinook were still rather widely scattered throughout the area and seemingly most abundant in the northwestern section. In July (Figure 9), chinook were apparently more abundant than in May and June and were found throughout nearly the whole of the area fished and as far south as fishing was carried out. While fishing was more extensive in August (Figure 10), most chinook salmon were taken in a band near the Aleutian Chain about

four degrees of latitude wide. The only chinook caught in September (Figure 11) were in the same band.

Attu to Kuril Islands. In May (Figure 7), chinook were most abundant in the south and southeast parts of the general area, while none was caught near Kamchatka and only a few in the north near the Aleutian Chain. In June (Figure 8), chinook were apparently more abundant over a larger section in the southern part of the area than in May. The concentrations found in May near 165°E and 44°N were less apparent, perhaps due to the paucity of fishing in this section. A few were still taken close to the Aleutian Chain and a few were taken closer to Kamchatka. In July (Figure 9), the sections of principal abundance were in the southern part of the area. The greatest concentrations of chinook for all areas and all time periods were to the southeast. In August (Figure 10), limited fishing in the northwest section of the area resulted in catches throughout the section.

Okhotsk Sea

After fishing started in June (Figure 8), chinook salmon were found close to the western shores of the more northern Kuril Islands and the southwest Kamchatka Peninsula. None was caught in the few fishing positions in the southern central Okhotsk Sea area. In July (Figure 9), the area of principal abundance was along the west coast of the Kamchatka Peninsula over the whole north to south range that was fished. Abundance along the Kuril Islands appeared to be reduced from that in June. In August, chinook were apparently less abundant than in June and July along the west coast of the Kamchatka Peninsula. They were generally absent from the northern central and southern sections of the Okhotsk Sea, although they were caught to the northeast of Sakhalin Island. Fishing was discontinued after August.

Sea of Japan

In 1962, Japan undertook a limited amount of exploratory fishing in the Sea of Japan in April and May. One chinook was caught close to the western shore of Hokkaido Island.

DISTRIBUTION AND ABUNDANCE DESCRIBED FROM RESEARCH VESSELS USING LONGLINES

Research vessels using longlines were operated by Canada in 1962 in the Gulf of Alaska area and westward approximating the longitude of Unimak Island as shown in Figures 14 through 17. While Japan also operated research vessels using longline gear, only that area between the longitudes of Attu and the Kuril Islands was fished enough to add to knowledge of

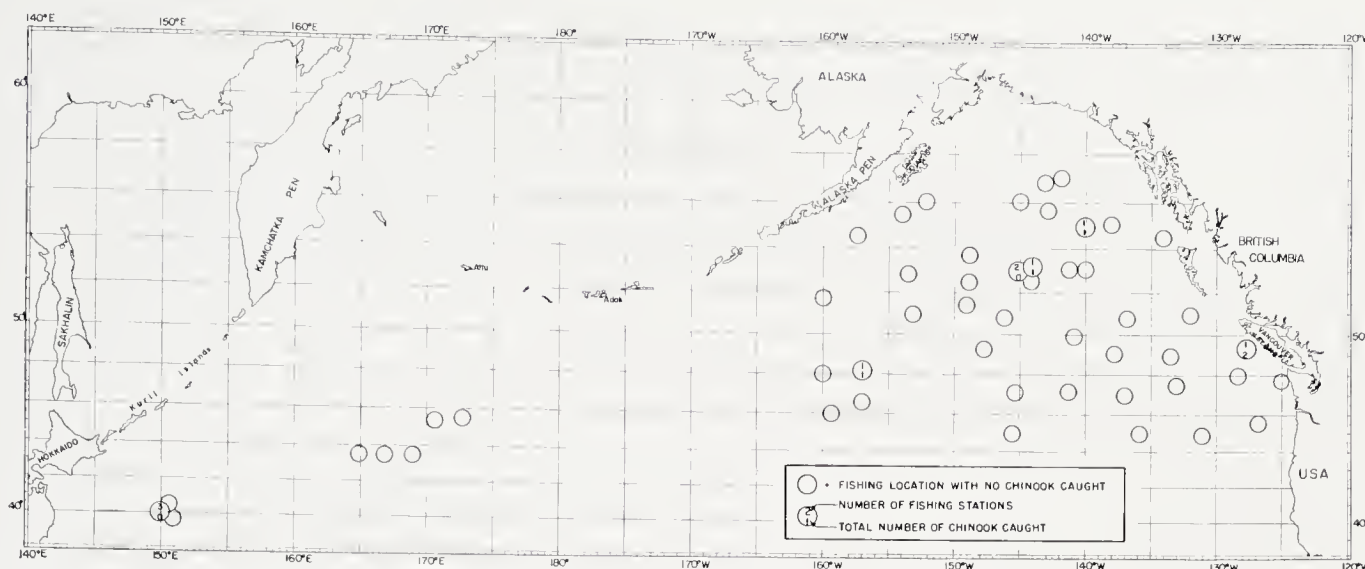


FIGURE 14. Longline fishing locations in *April* 1962 by research vessels of Canada and Japan.

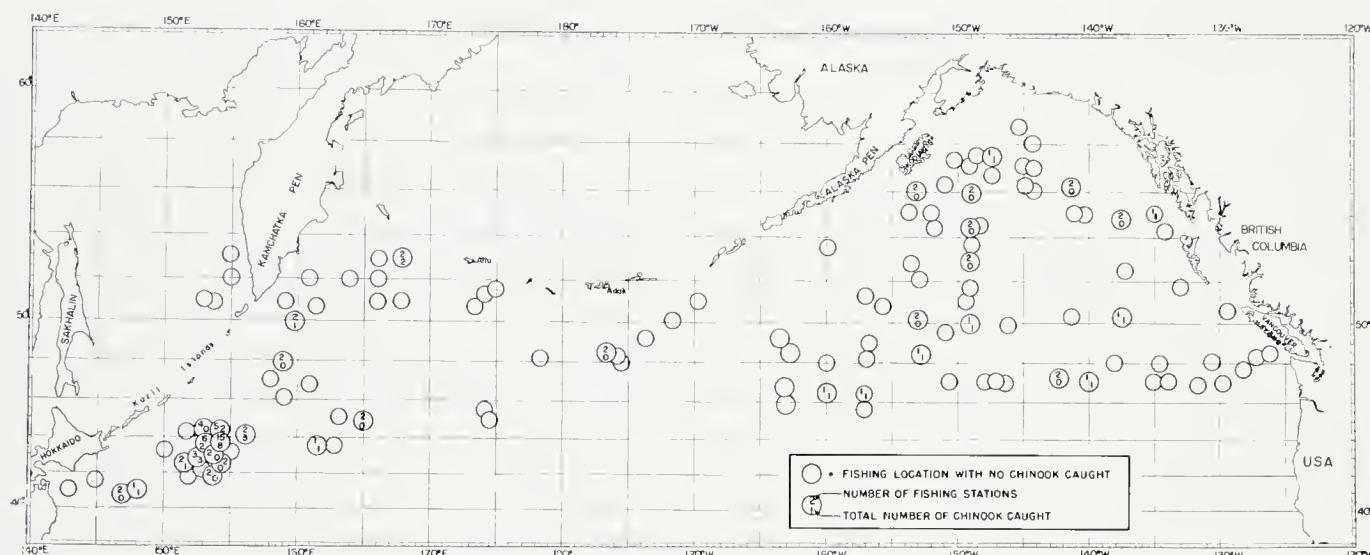


FIGURE 15. Longline fishing locations in *May* 1962 by research vessels of Canada and Japan.

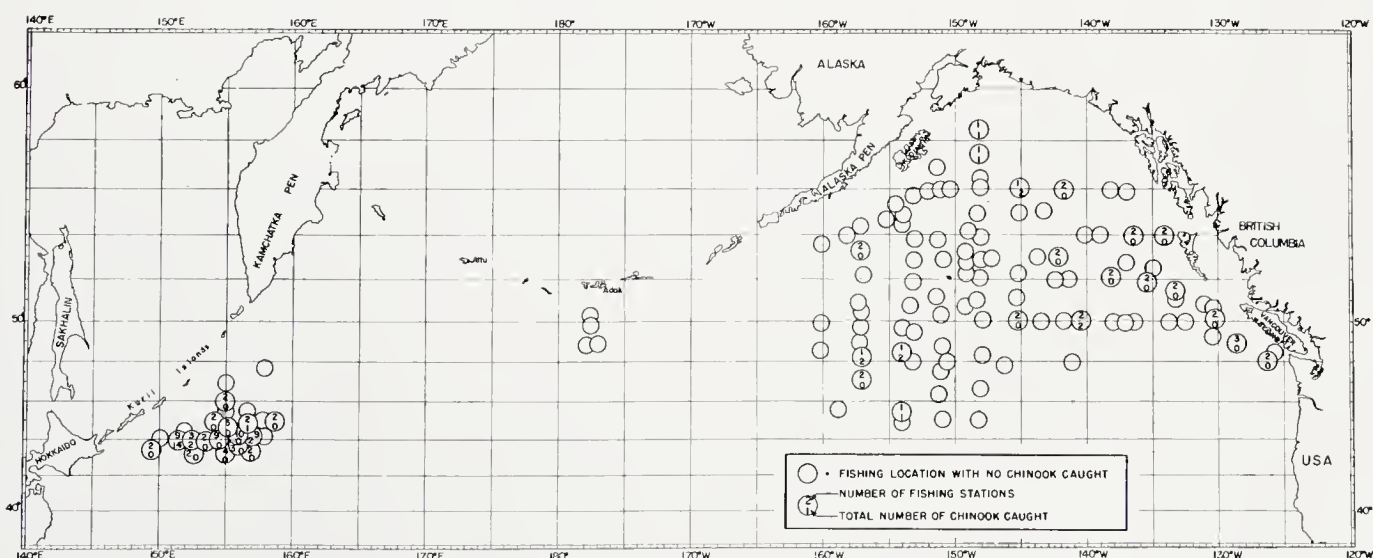


FIGURE 16. Longline fishing locations in *June* 1962 by research vessels of Canada and Japan.

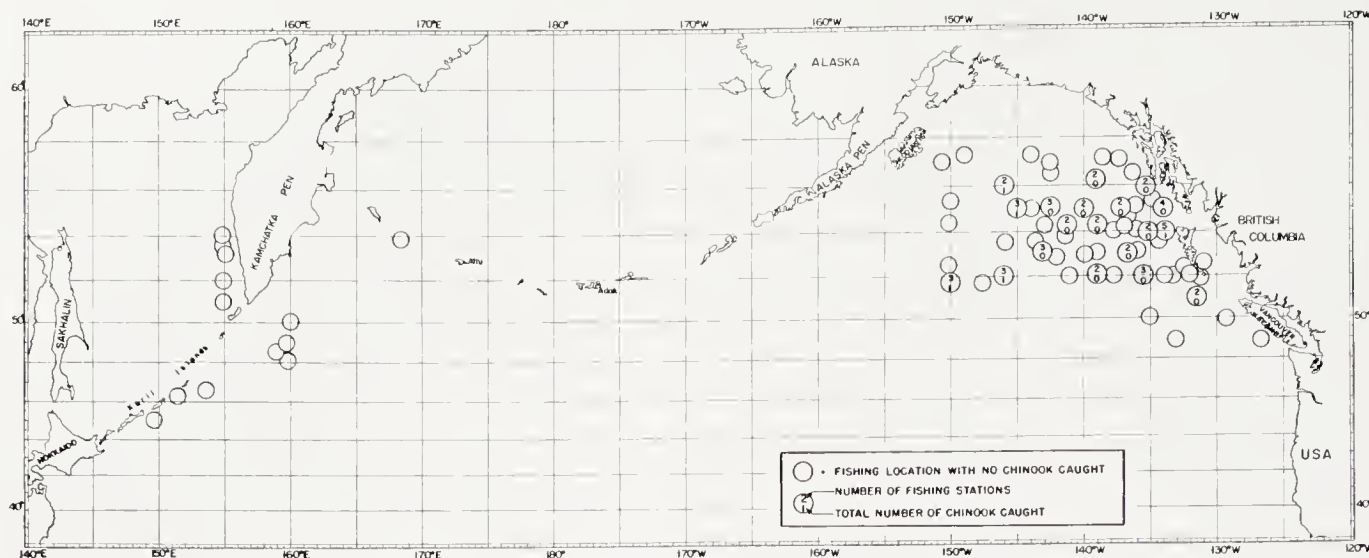


FIGURE 17. Longline fishing locations in July 1962 by research vessels of Canada and Japan.

distribution and abundance of chinook. The data in Figures 14 through 17 were taken from Neave *et al.* (1962) and Fisheries Agency of Japan (1962).

Gulf of Alaska

In April (Figure 14), a single chinook was taken southwest of Kodiak near the periphery of the area of fishing. Two others were taken to the northeast near the center of the Gulf. Figure 15, for May, shows that, aside from two chinook taken in the more northern periphery of the fishing area, no chinook were caught from the Gulf of Alaska and westward to about Unimak Island north of 51°N latitude. The six caught were taken west of 137°W longitude and south of 51°N latitude. In June (Figure 16), catches of chinook were similar in location to those in May, although the area fished was larger and fishing more intense. In July (Figure 17), the chinook taken in offshore waters were in the western and southern sections of the area fished.

Attu to Kuril Islands

Figure 15, for May, shows the principal area of chinook abundance to be eastward of Hokkaido Island near 155°E longitude. This was still the principal area of abundance in June. Longline fishing effort for earlier and later months was too scattered to add to the knowledge of distribution and abundance.

COMPARISON OF DISTRIBUTION AND ABUNDANCE BASED ON GILLNET AND LONGLINE CATCHES OF RESEARCH VESSELS

Comparisons of the distribution of chinook salmon as described from longline and gillnet catches can be made only for the Gulf of Alaska area and the area eastward of Hokkaido. While the longline data are

for 1962 only, it is assumed that they will serve as an index of chinook distribution for all years.

Gulf of Alaska

The chinook caught by longlines in April (Figure 14) established their presence in the Gulf of Alaska in that month where none had been taken by gillnets. Longline catches as shown in Figure 15 extended the May range further to the south and west and slightly eastward from that shown by gillnets (Figure 7). In June (Figure 16), longlines took chinook south and southwest of Kodiak and extended the range to the south of the areas fished by gillnets (Figure 8).

Attu to Kuril Islands

The area of highest abundance indicated by longline fishing and that indicated by gillnet fishing in the same season is generally the same in the region east of Hokkaido Island. Data for other parts of this general ocean area are not comparable due to the scattered longline fishing operations.

DISTRIBUTION DESCRIBED FROM JAPANESE MOTHERSHIP OPERATIONS

Summaries of the number of chinook caught and catch per 100 tans by month and by areas for the combined years 1954 through 1961 by the Japanese mothership fisheries are given in Figures 18 through 21 as compiled from INPFC Statistical Yearbooks 1955 through 1961. These figures show chinook occurring from at least 46°N to 62°N latitude and from 175°W longitude (the eastern fishing boundary) to the Kamchatka Peninsula. No differences in distribution by months can be noted, since chinook were to be found in all the areas where the fleet operated in one or more of the years.

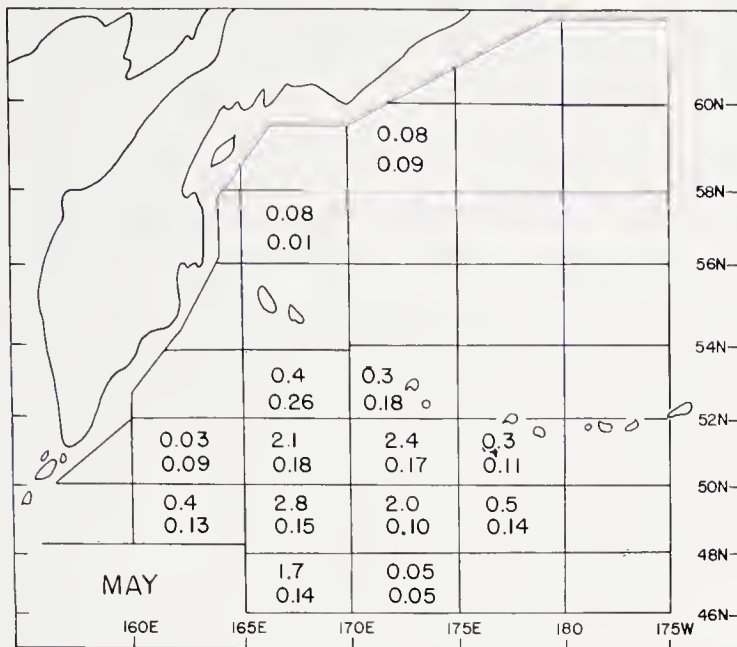


FIGURE 18. Thousands of chinook salmon caught (upper numerals) and catch per 100 tans (lower numeral) in the Japanese mothership fishery, May, 1954 through 1961. Data from INPFC Statistical Yearbooks 1954-1961.

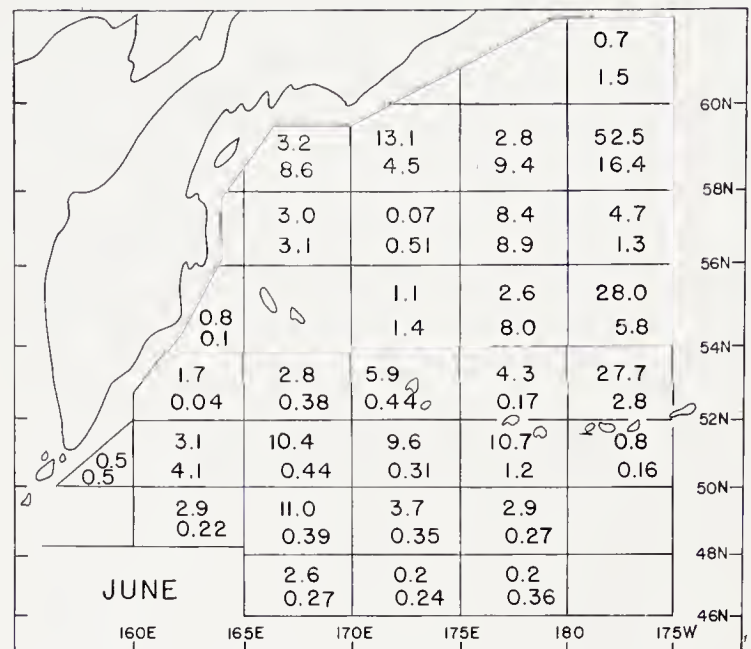


FIGURE 19. Thousands of chinook salmon caught (upper numerals) and catch per 100 tans (lower numeral) in the Japanese mothership fishery, June, 1954 through 1961. Data from INPFC Statistical Yearbooks 1954-1961.

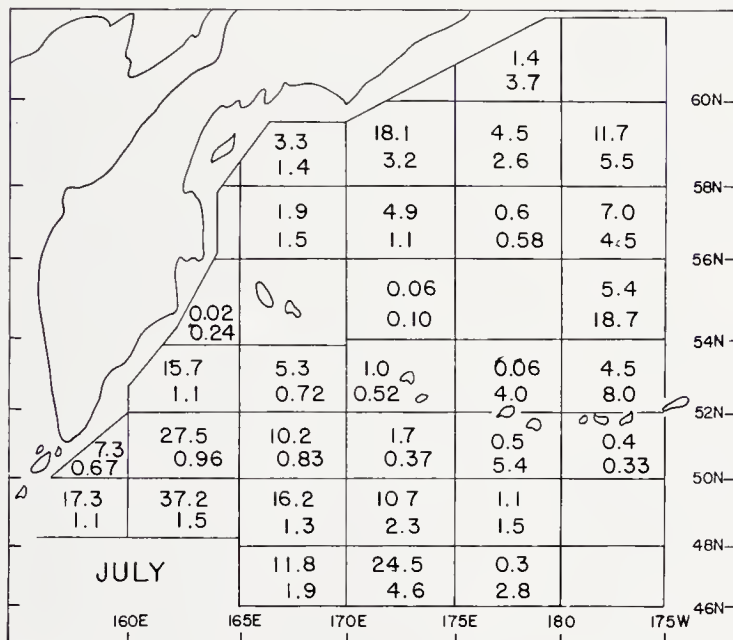


FIGURE 20. Thousands of chinook salmon caught (upper numerals) and catch per 100 tans (lower numeral) in the Japanese mothership fishery, July, 1954 through 1961. Data from INPFC Statistical Yearbooks 1954-1961.

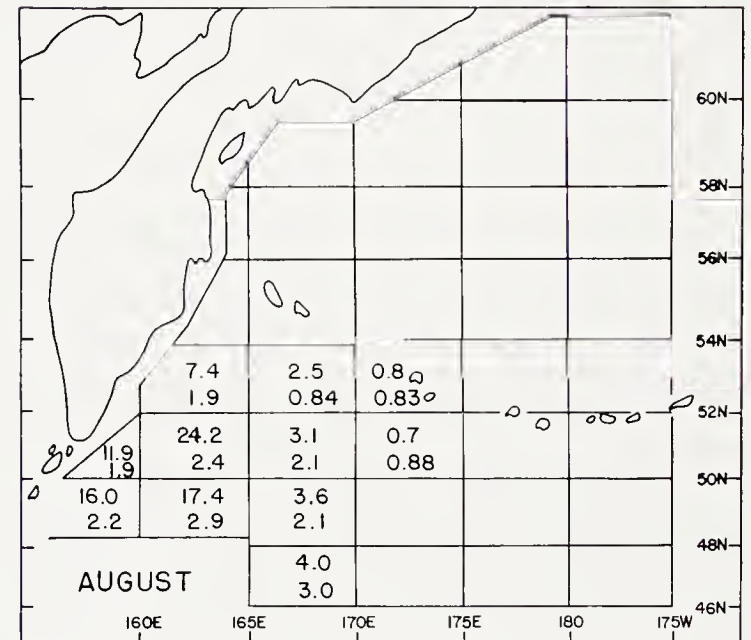


FIGURE 21. Thousands of chinook salmon caught (upper numerals) and catch per 100 tans (lower numeral) in the Japanese mothership fishery, August, 1954 through 1961. Data from INPFC Statistical Yearbooks 1954-1961.

The mothership data for the years 1952 and 1953 were also examined for indications that would broaden the knowledge of distribution. No information that would add to the conclusions for the combined years 1954 through 1961 was found.

Bering Sea data for interpretation of abundance in

May and August are too few for evaluation, except to note that the area of principal catch was southeast of Kamchatka. The areas of largest catches in June centered around the Aleutian Islands between 175°E and 175°W longitude in the Bering Sea and southeast of Kamchatka (Figure 19). In July (Figure 20), the largest catches were made to the northwest toward

Oliutorski in the Bering Sea. Thus, a shift to the west is indicated in July followed by a further shift in August. In July, the chinook catches southeast of Kamchatka were higher than in all the other months and closer to coastal waters.

Chinook salmon were landed in the Okhotsk Sea in those years when a Japanese mothership fishery existed there. Fishing started in June south and west of the Kamchatka Peninsula, reached a peak in the same area in July, and ended in August.

The principal areas of abundance as shown by the catch per 100 tans were somewhat different from those shown by the catch in each area. In May, they were the same—southeast of Kamchatka (Figure 18). In June (Figure 19), the catch per 100 tans showed a greater abundance near 58°N latitude in the Bering Sea, as compared to the latitude of the Aleutian Islands shown by catches. Both catches and catches per unit of effort showed the center of abundance south of the Aleutians to be southeast of Kamchatka. While July catches in the Bering Sea were highest near Oliutorski, the catches per unit of effort showed that chinook were relatively abundant not only in that area, but also along the eastern fishing boundary. Catches and catches per unit of effort coincide reasonably southeast of Kamchatka.

AGE, SEX AND MATURITY IN OFFSHORE WATERS

The only data available for age and sex composition studies of chinook salmon are from Manzer *et al.* (MS1963) from samples taken in the Japanese mothership and landbased fisheries in 1960 (Table 10). (Research vessel data had not been tabulated nor collated at the time this manuscript went to press.) It should be recognized that these data are limited. They represent only one year and they concern only the fish caught, since no data are available as to either the effects of gear selectivity or the areas of sampling as related to the distribution of chinook salmon populations.

Ages and Sex Ratios

The age composition changed in all areas during the course of the fishing season (Table 10). Chinook salmon in their fourth year which had gone to sea in their second year (4_2 's) were most abundant in the samples, followed by fish in their fifth year which also had left fresh water in their second year (5_2 's). The data also indicate that as the season progressed the abundance of 5_2 chinook declined and that of 4_2 's increased, 4_2 's becoming predominant in the samples. By July and August, the abundance of 5_2 's had decreased appreciably from the levels indicated in May and

June except in the area west of 170°E where the decrease was not as great and interpretation limited by small samples in August.

In sex identification, 911 chinook salmon were identified as females and 948 as males, an approximately 50–50 ratio. The sex ratio was different, however, by (1) age groups, (2) by time of season within areas and (3) between areas. Excluding the land-based region data because of lack of sex-classified samples in the 5_2 age group, in the 4_2 age group, females comprised about 40 percent of the samples, compared to about 63 percent in the 5_2 age group.

In the east of 170°E-south of 52°N and west of 170°E areas, the percentage of females generally increased as the season progressed, while it decreased slightly in samples in the area east of 170°E-north of 52°N. The several small samples in the landbased fishery do not permit any interpretations of changes in sex ratio within the season. In the landbased fishery, 4_2 age group females were almost 51 percent of the samples, compared with 42 percent for all areas combined.

Average Length

The published research vessel data include length measurements from 33 chinook salmon reported by Powell and Peterson (1957) and a statement by Hartt (1962) to the effect that chinook caught for tagging purposes varied in size from 21 to 84 cm. These data are obviously inadequate for length analysis.

Dr. Hanamura of the Japanese Fisheries Agency supplied the data for Table 11 from the mothership fishery. These data show that females were almost always larger than males in all samples collected during May through August in the four years in which samples were taken. It is also apparent that for both males and females the average length per sample decreased in the period May through August in all years in all areas. The few exceptions were the 1958 samples from the Okhotsk Sea in June through July.

It should be noted in relation to the apparent greater sizes of females and their declining average length in relation to time, that males outnumbered females in May and June (combined year data) in all areas where significant sample sizes were obtained, except in the Bering Sea, where there were a few more females than males. In July and August, males again outnumbered females except in the Aleutian and Bering Sea samples. These data show that while males were generally more abundant in the samples, females were generally larger at any time during the fishing season in most areas. The reasons for these

TABLE 10. Age composition of samples of chinook salmon caught by mothership and landbased fisheries in 1960, with the sex ratio of age 4₂ and age 5₂ fish¹⁾.

Area	Month	Age								Sample size	No. of 4 ₂ 's and 5 ₂ 's identified by sex
		3 ₂	4 ₂	4 ₃	5 ₂	5 ₃	6 ₂	6 ₃	7 ₃		
East of 170°E, South of 52°N	MAY										
	Percent		15		76		3		6		
	Number		5		26		1		2	34	
	% Male		80		27						11
	% Female		20		73						20
	JUNE										
	Percent		35		54		5	3	3		
	Number		32		49		4	3	3	91	
	% Male		72		49						47
	% Female		28		51						34
	JULY										
	Percent	1	85		9	5		1			
	Number	1	140		14	8		1		164	
	% Male		53		43						80
	% Female		47		57						74
	AUGUST										
	Percent		90		10						
	Number		7							8	
	% Male		57								4
	% Female		43								3
	Total males		105		37						142
	Total females		79		52						131
	% males		57.1		41.6						
	% females		42.9		58.4						
East of 170°E, North of 52°N	JUNE										
	Percent		51		38	6	1	4			
	Number		236		177	28	5	19		465	
	% Male		53		33						183
	% Female		47		67						230
	JULY										
	Percent	4	52		23	16		5			
	Number	2	29		13	9		3		56	
	% Male		55		31						20
	% Female		45		69						22
	AUGUST										
	Percent		74		26						
	Number		14		5					19	
	% Male		57		40						10
	% Female		43		60						9
	Total males		149		64						213
	Total females		130		131						261
	% males		53.4		33.8						
	% females		46.6		67.2						

Continued

TABLE 10. (Continued)

Area	Month	Age								Sample size	No. of 4 ₂ 's and 5 ₂ 's identified by sex
		3 ₂	4 ₂	4 ₃	5 ₂	5 ₃	6 ₂	6 ₃	7 ₃		
West of 170°E	MAY										
	Percent		23		45	2	13	13	4		
	Number		16		33	1	9	9	3	71	
	% Male		81		49						29
	% Female		19		51						20
	JUNE										
	Percent		38		43	4	6	7	2		
	Number		121		136	13	19	22	6	317	
	% Male		81		41						154
	% Female		19		59						103
	JULY										
	Percent	1	59	1	31	4		4			
	Number	7	398	7	209	27		27		675	
	% Male		59		36						310
	% Female		41		64						297
	AUGUST										
	Percent		89		11						
	Number		8		1					9	
	% Male		38								3
	% Female		62		100						6
	Total males		349		147						496
	Total females		194		231						425
	% males		64.3		38.8						
	% females		35.7		61.2						
Landbased, North of 45°N	JULY										
	Percent		84		11	1		4			
	Number		58		8	1		3		70	
	% Male		45								26
	% Female		55								32
	AUGUST										
	Percent	4	59		30	4		4			
	Number	1	16		8	1		1		27	
	% Male		44								7
	% Female		56								9
	Total males		33								33
	Total females		41								41
	% males		44.6								
	% females		55.4								

Continued

differences cannot be ascertained.

MIGRATION AND VERTICAL MOVEMENT IN OFFSHORE WATERS

While the material presented in Figures 7 through 13 suggests seasonal changes in horizontal distribution of chinook salmon, the deficiencies inherent in these data prevent any quantitative inferences concerning migration of chinook salmon on the high seas.

Powell and Peterson (1957) presented data which indicated that a greater percentage of chinook were caught in the lower two-thirds of a gillnet hanging approximately 20 feet into the water. No other data have been found concerning vertical migrations or distribution on the high seas. There is some information from North American commercial coastal trolling operations that chinook salmon may be further below the surface than coho salmon caught in the same area, but this information does not necessarily

TABLE 10. (Continued)

Area	Month	Age								Sample size	No. of 4 ₂ 's and 5 ₂ 's identified by sex
		3 ₂	4 ₂	4 ₃	5 ₂	5 ₃	6 ₂	6 ₃	7 ₃		
Landbased, South of 45°N	MAY										
	Percent		50		50						
	Number		6		6					12	
	% Male		33								2
	% Female		67								4
	JUNE										
	Percent		50			41	9				
	Number		11			9	2			22	
	% Male		64								7
	% Female		36								4
	JULY										
	Percent		84		12	3		1			
	Number		100		14	4		1		119	
	% Male		55								55
	% Female		45								45
	Total males		64								64
	Total females		53								53
	% males		54.7								
	% females		45.3								
All areas	Total males		700		248						948
	Total females		497		414						911
			1,197		662						1,859
	Percent males		58.5		37.5						
	Percent females		41.5		62.5						

¹⁾ Data from Manzer *et al.* (MS 1963), Tables 40 and 42, and calculations based thereon.

apply to the offshore waters (Milne, 1955).

No data have been found that would allow any comment on distribution and abundance of chinook as affected by oceanographic conditions.

IDENTIFICATION AND SEPARATION OF STOCKS OR RACES

Only limited effort has been directed toward methods of identifying the continental origin of oceanic chinook salmon. Tagging for this purpose has indicated the probability of some intermingling of immature chinook from both continents (Figure 22). There were seven returns from over 900 chinook tagged west of 155°W longitude by Japanese and United States research vessels in the years 1956 through 1960 (INPFC, 1957-1961). With the exception of one chinook tagged and recovered by Japanese scientists, all were recaptured either one or two years after tagging. An examination of tagging data given in the INPFC Annual Reports (1956 through 1960) showed that about 94 percent of the chinook tagged by United States vessels was estimated to consist of immatures at time of tagging. Data on maturity were not available

from the Japanese experiments.

The estimated 94 percent composition of immatures, the delay of one to two years in time of recapture, the apparent direction of migrations from a nearly common tagging point south of Adak and the apparent crossing of migration paths in the Bering Sea are interpreted as being evidences of the intermingling of immature chinook stocks from the two continents. The lack of data for chinook salmon tagged and recovered in the same year prevents any such statement for mature fish.

It is also apparent that the data are too few to allow any comments as to origin within continents. However, the two recoveries from the Yukon and the Columbia River systems indicate that a wide geographical range is quite possible.

DISCUSSION

The data used in this report were collected over nearly a century. They represent programs varying from small isolated pieces of research to coordinated

TABLE 11. Mean lengths of chinook salmon taken in areas fished by the Japanese mothership fishery¹⁾.

Area	Year	Sex	May		June		July		August		Total
			Cm	No	Cm	No	Cm	No	Cm	No	
Aleutian	1957	F	78.3	58	61.7	205	55.2	93	—	—	
		M	70.7	100	59.1	227	54.1	87	—	—	
	1958	F	74.9	78	66.6	133	—	—	61.9	62	
		M	64.9	86	62.7	223	—	—	62.4	39	
	1959	F	82.5	5	67.1	113	60.1	198	—	—	
		M	59.8	13	61.7	186	58.7	167	—	—	
	1960	F	72.5	26	72.3	55	60.3	123	64.5	4	
		M	72.4	18	63.8	72	60.8	130	59.8	6	
	Total	F		167		506		414			1063
		M		217		708		384			1254
Bering Sea	1959	F	—	—	64.4	49	60.6	403	—	—	
		M	—	—	62.8	64	59.4	360	—	—	
	1960	F	—	—	61.5	420	59.9	49	66.1	11	
		M	—	—	59.8	392	58.8	48	62.8	19	
	Total	F				469		452			932
		M				456		408			883
Kamchatka-Kuril	1957	F	71.3	3	65.0	21	62.0	87	—	—	
		M	71.3	18	63	40	61.7	103	—	—	
	1958	F	72.1	168	68.6	848	62.0	1167	61.1	435	
		M	66.7	212	62.7	1200	61.2	1287	60.9	351	
	1959	F	78.1	50	65.8	115	62.6	143	—	—	
		M	64.1	93	61.2	228	61.2	170	—	—	
	1960	F	77.3	54	70.2	197	64.0	609	64.2	13	
		M	69.4	55	65.4	234	62.0	685	64.0	20	
	Total	F		275		1181		2006			3462
		M		378		1702		2245			4325
Okhotsk	1957	F	—	—	99.	1	64.4	14	—	—	
		M	—	—	68.1	27	60.5	46	—	—	
	1958	F	—	—	57.3	23	63.0	21	60.0	2	
		M	—	—	60.7	51	61.2	42	60.0	2	
	Total	F				24		35			59
		M				78		88			166
Landbased, North of J-S Treaty line	1960	F	—	—	—	—	60.1	42	59.9	21	
		M	—	—	—	—	61.8	36	60.7	22	
Landbased, South of J-S Treaty line	1960	F	56.0	5	71.9	13	58.5	61	—	—	
		M	69.1	8	63.5	11	59.9	80	—	—	
Total		F									142
		M									157
Total		F									5658
		M									6785

¹⁾ Data supplied by N. Hanamura of the Japanese Fisheries Agency.

programs concurrently pursued by several fishery agencies. In spite of the elapsed time and the discontinuity in certain research efforts, some features are apparent that are pertinent to knowledge of the offshore distribution of chinook salmon.

Coastal tagging has shown that chinook salmon migrate in substantial numbers from the Columbia River, and even from as far south as the Sacramento River, to Alaskan and British Columbian waters. Consistent with this is the fact that the most northerly

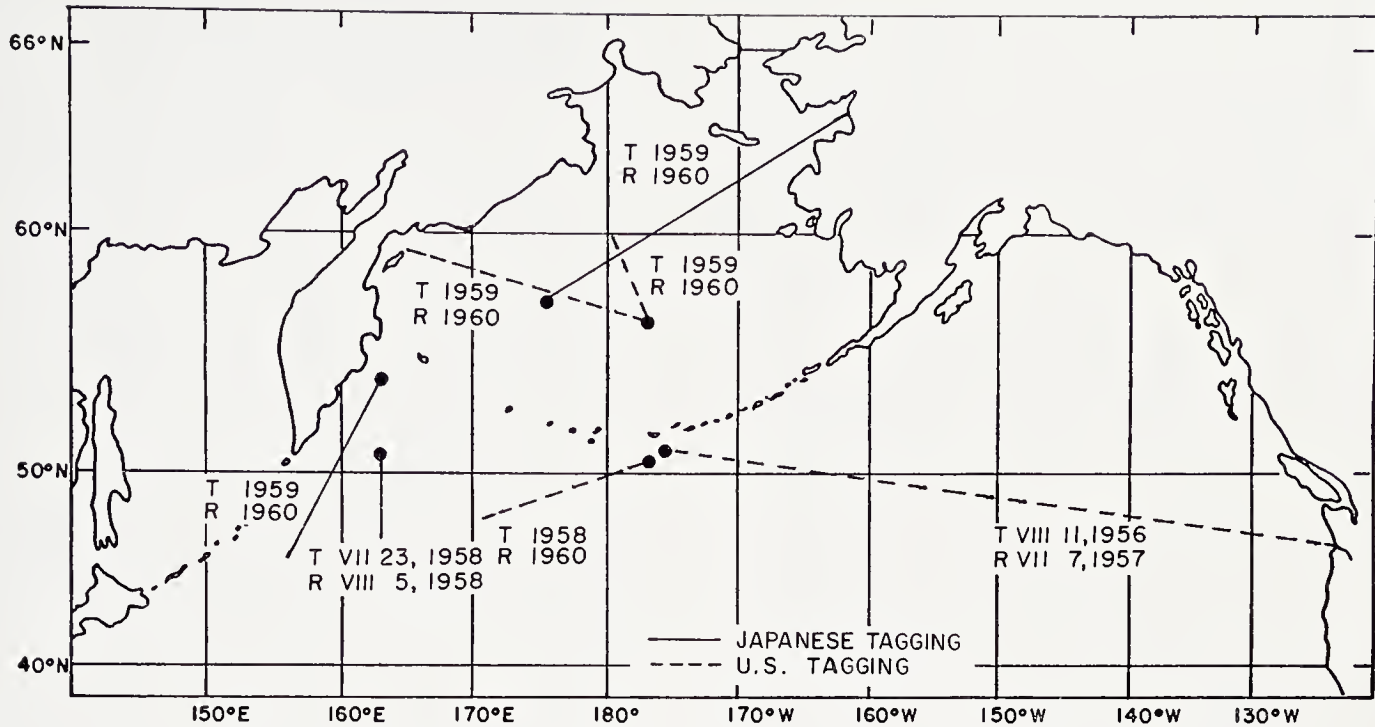


FIGURE 22. Recoveries of chinook salmon from tagging by Japanese and United States research vessels. Data from Godfrey (1961) and Hartt (1962).

recovery of a chinook salmon marked by fin excision was a fish from an early run Columbia River race. A difference in proportion of ocean type scales for chinook salmon leaving fresh water is indicated between southern and northern latitudes as shown from samples from the Taku and Yukon Rivers which were almost exclusively stream type scales, while in the area between the Taku and Sacramento Rivers some 70 to 90 percent were ocean type scales. (No samples were available to show where this change in composition occurred in relation to the geographical distribution of chinook salmon.) These factors suggest the possibility that the early run chinook of the Columbia River and elsewhere, which have a predominance of stream type scales, may mature in waters north (and west) of Cape Spencer. The fact that early run races of Columbia River chinook do reach Aleutian waters was established by the recovery in the Salmon River (an upper Columbia River tributary) of a fish tagged south of Adak as an immature. A possible migration route along the Aleutians for immature chinook salmon was noted from differences in catches between purse seine sets open to the east as compared with sets open to the west as well as an increase in abundance in June and July.

A limited number of scale samples from chinook taken by the Japanese mothership fishery failed to reveal a single instance of an ocean type scale. This may be due to the method of sampling, or even the possibility of a difference in method of interpreting

scales. Until such time as additional data are found, present information indicates that any chinook that might be of North American origin and that might be taken in the Japanese mothership fishery would be from the more northern rivers or from early races of the more southern rivers.

It was noted that research vessels caught very few chinook salmon in a band running southeast from the Kenai Peninsula to the Oregon coast. Chinook have been caught both east and west of this band suggesting the possibility of a zone of delineation between populations. This apparent zone might be an artifact resulting from selectivity of the gear, a different vertical distribution of fish in this area, or even from the oceanographic conditions that existed. Still another possibility is that fishing in this band at other times of the year might have resulted in chinook catches. Whatever the reasons for the apparent existence of this band, they are not apparent in the data available.

SUMMARY AND CONCLUSIONS

This report has been based almost entirely on published information which was used without critical review or comment although some of the deficiencies and limitations were noted. The data were comparatively few, collected in widely scattered places and times, and usually collected for other purposes than

the objectives of this report. Therefore, the following conclusions are considered as tentative.

(1) Chinook salmon are found in North America from the Monterey Bay area to the Chukchi Sea. On the Asian coast, they occur from the Anadyr River area southward to Hokkaido. The larger populations are usually associated with the larger river systems.

(2) Total North American chinook catches greatly exceed those of Asia. In the period 1954 through 1961, the combined catches by U.S.S.R. and Japan have ranged from 96,000 chinook to 250,000 as compared with 2,456,300 to 3,664,200 chinook for the United States and Canada. Additional numbers were taken in North American sport fisheries.

The overall trend since World War II has been toward increased catches in both North America and Asia. Increased catches in Asia are attributable to additional fishing effort in the Japanese high seas fishery, starting in 1952, and increased Soviet coastal catches. The North American trend since 1946 toward increased catches is the resultant of declining catches in United States fisheries and increasing catches in British Columbia fisheries.

North American chinook catches, mostly from troll fisheries, start early in the spring and are much reduced after August. The specific dates are determined by regulations and characteristics of the populations in particular fishing areas.

Chinook salmon are occasionally taken in the Japanese coastal fisheries in November through January, although most are taken in April, May and June. In the Japanese mothership fishery, they are taken in the months of May through August with the peak usually occurring in July. Chinook catches on the East Kamchatkan coast are higher than those on the west coast and peak in June, although catches occur from May through August.

Since few escapement figures are available on either continent, it cannot be maintained with certainty that the population magnitudes are directly proportional to the catch.

(3) In North America, different river systems may characteristically have from one to several commercially fished runs of chinook, with southern rivers having more runs than northern rivers. Each such run may be composed of one or more races each destined for a particular spawning area. At the present time there are no demonstrated methods of identifying a particular race of chinook salmon prior to its arrival on its spawning grounds.

(4) In North America, chinook salmon migrate to the sea as yolk-sac fry, as fingerlings or yearlings, and sometimes at greater ages. They may pass through brackish water immediately or remain there for an indefinite period of time. Most apparently migrate towards the north, although some may migrate to the south and some may remain in the general area of the stream of their origin.

(5) North American scale samples showed that the age at maturity varies from two to seven years. In more southern waters, chinook salmon mature more commonly in their fourth and fifth years of life and in their fifth to sixth year of life in more northern waters. South of the Taku River, most scale samples were of the ocean type. In the Taku River and the Yukon River, all were of the stream type. Present data do not establish precise geographical areas of transition.

(6) For maturing chinook salmon, various tagging experiments show a positive southward migration in coastal waters off southeastern Alaska and British Columbia.

(7) Data from the Asian coast are either not presented in sufficient detail or are not available to establish the existence of various runs and races or describe variations in size of downstream migrants or the time of their migration. Coastal migrations, marine life history and age at maturity also are not adequately defined for Asian fish.

(8) The data from research vessels of Canada, Japan and the United States, and from the Japanese mothership fishery indicate that chinook may generally be found across the Pacific Ocean from at least 41°N latitude to the Aleutian Chain in the months of June through August. No chinook were caught in this period in a rather broad band running from the Kenai Peninsula southeast to the Oregon coast.

In June, chinook salmon were found in the Bering Sea westward from Bristol Bay to Kamchatka and northward from the Aleutian Islands to 60°N latitude. Greatest concentrations appeared to be in the central Bering Sea area. In July, the concentration apparently shifted to the westward of 180°, followed by a further westward shift in August. There was no September fishing in the area.

In May, chinook were found south of the Aleutians to 42°N latitude in the central North Pacific and to 40°N latitude close to Japan. The area of greatest abundance appeared to be south of the Komandorski Islands and east to 175°E longitude. The apparent

abundance in this area increased in June, reached a peak in July and declined in August. At the same time, the zone of greatest abundance apparently moved westward toward the coast of Kamchatka.

The pattern of a westerly movement of immature chinook with increased abundance in June and peak abundance in July was also observed south of and in close proximity to the Aleutian Islands at and west of Adak. This suggests a possible route by which chinook of North American origin might enter areas fished by the Japanese mothership fishery in some years.

(9) Since surface fishing gillnets, selective as to size of chinook caught, were used in both research and commercial operations, any conclusions reached on offshore distribution and abundance may apply only to the sizes of chinook caught in these surface waters and not to the total population which may have been present.

(10) Limited samples taken from the Japanese mothership fisheries in 1960 indicated that 4₂ chinook salmon were most abundant, followed by the 5₂'s. All scale samples were of the stream type. The age composition changed with the season, older fish being more common earlier in the season.

While the sexes were evenly divided in the combined samples from the mothership and landbased fisheries, the sex ratio differed by ages, by time within areas and between areas. Males generally outnumbered females and the females were generally larger than the males in samples from the mothership fishery.

(11) No quantitative statements can be made on vertical or horizontal migrations, or on identification and separation of continental stocks, or on the degree of intermingling of mature and immature chinook salmon in offshore waters. However, the data show that migrations and intermingling do occur.

(12) There is an indication from one tag recovery that early run chinook races from the more southern North American rivers occur in waters of the central North Pacific Ocean as immatures.

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SALMON OF THE NORTH PACIFIC OCEAN—PART IX COHO, CHINOOK AND MASU SALMON IN OFFSHORE WATERS

3. A REVIEW OF THE BIOLOGICAL INFORMATION ON MASU SALMON (*ONCORHYNCHUS MASOU*)

by

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Tokai Regional Fisheries Research Laboratory, Tokyo, June 1963

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FOREWORD

In this report, literature on masu salmon published in Japan and the U.S.S.R. is introduced and sum-

marized. In addition, information obtained from the Japan Sea Regional Fisheries Research Laboratory, Hokkaido Regional Fisheries Research Laboratory, Hokkaido Prefectural Fisheries Experimental Station and Hokkaido Salmon Hatchery was analyzed together with some data collected by the author.

In this work, many scientists from the agencies mentioned above have assisted by providing much unpublished data, by suggesting some of the analyses and in many other ways. The author would like to express his gratitude to these persons.

1. INTRODUCTION

1.1 CLASSIFICATION

The scientific name for masu salmon (sakura-masu) is *Oncorhynchus masou* var. *masou* (Brevoort). Yamame, *O. masou* var. *ishikawae* (Jordan and McGregor), is the freshwater type of masu salmon. Yamame can be separated from biwamasu, *O. rhodurus* var. *rhodurus* (Jordan and McGregor), and amago, *O. rhodurus* var. *macrostomus* (Günther), by the absence of vermilion spots. Biwamasu and amago both occur in southern Japan; biwamasu is the lake-type while amago is the stream-type. (Oshima, 1957; Matsubara, 1955.) Since feeding experiments suggest that the vermilion spots are a genotypic character, these fishes are tentatively treated as different species. It should be noted, however, that when masu salmon and amago were crossbred and the offspring mated, the second generation showed good growth (Oshima, 1957). This experiment indicated that the two species in question are very closely related, even if they are separate. Imanishi (1951) considered that from an ecological standpoint they only represented a single species.

Masu salmon resemble coho salmon, *Oncorhynchus kisutch* (Walbaum), in morphological as well as ecological aspects (Hikita, 1956). The fact that the geographical distribution of masu salmon is separated almost completely from that of coho salmon is suggestive of competition which might be construed as further evidence of the close relationship of these two species (Birman, 1953).

1.2 GEOGRAPHICAL DISTRIBUTION

Masu salmon have a rather southerly distribution and they occur in streams farther south than those inhabited by other species of the genus *Oncorhynchus*. The species is restricted to the Asian side of the North Pacific, none ever having been found in North America.

On the Pacific side, their spawning streams are found north of Chiba Prefecture. In the Sea of Japan, they occur north of Shimane Prefecture in Japan and along the eastern coast of Korea north of the Racktong River (Yoshida, 1942). The distribution of masu salmon along the coasts of the Sea of Japan extends northward through North Korea and Primorskaia to the estuary of the Amur River on the continental side and through Honshu and Hokkaido to the west coast of South Sakhalin on the island side.

In Hokkaido, masu salmon are found in all coastal areas. They occur rarely in the Kuril Islands, and are present on the west coast of the Kamchatka Peninsula. It is reported that some even occur on the east coast of the Kamchatka Peninsula. It is also reported that in 1954 the masu salmon run in the Utka River on the west coast of the Kamchatka Peninsula consisted of some 10,000 fish. (Semko, 1956.) In some unusual cases, a few masu salmon were reported in the East China Sea, along the west coast of Kyushu, Japan, and along the west coast of Korea (Matsubara, 1934; Yoshida, 1938).

In Japan, the center of distribution of masu salmon is in Hokkaido. On the U.S.S.R. coasts, the relative importance of masu salmon in catches of the genus *Oncorhynchus* is rather low. They seem to be most abundant in the northern Primorskaia area. (Pravdin, 1949.)

Very little is known about their oceanic distribution. In the spring, they are distributed all through the northern part of the Sea of Japan, but practically no information is available on their distribution in the Pacific Ocean. It is considered that this species is of a coastal nature compared with other species of *Oncorhynchus*.

The geographical distribution of yamame, the freshwater-type masu salmon, extends farther south. The distribution covers all of Japan, except some southern parts where only *O. rhodurus* is found. Freshwater-type masu salmon are even found in the Taiko River in Taiwan (Oshima, 1957).

1.3 REVIEW OF FISHERIES

Generally speaking, masu salmon are fished in coastal waters. However, in the Sea of Japan, the offshore drift gillnet fishery does catch some masu salmon.

On the Pacific coast of Honshu, Japan, mostly north of Miyagi Prefecture, masu salmon fishing is carried out from March to September with trap-nets, coastal longlines, gillnets and various other less important

methods. The peak of the fishing season is in April and May. It should be noted that the gear used in this fishery is carried by small fishing vessels and that the object of the fishery is species other than salmon.

Along the Japan Sea coast of Honshu, mostly north of Ishikawa Prefecture, masu salmon are fished from January to June with such kinds of gear as trap-nets, longlines and handlines. The peak of the fishing season is in March in the southern areas and in April or May in the northern areas. The masu salmon taken by drift gillnet fisheries in offshore areas of the Sea of Japan are landed mostly in March, the first month of fishing. However, the season does continue on through June. In the earlier part of the season, the area between 38°N and 40°N forms the main fishing ground, but as the season progresses the fishing ground shifts towards the north and by June it reaches the area off the northern part of Hokkaido Island.

In Hokkaido, masu salmon are abundant all along the Japan Sea coast and on the Pacific coast west of Hidaka. On the Japan Sea coast of Hokkaido, the most popular gear for masu salmon fishing is the handline. Although the earliest catches might be made as early as November, most catches are made from January to June, with fishing reaching a peak in April and May. (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956; Konda *et al.*, 1952.) There are also trap-net catches of masu salmon made from April to June. On the Pacific coast of Hokkaido from Hidaka to Oshima via the Iburi region, the peak of the masu salmon fishing by trap-nets occurs in June. On the Okhotsk coast and Nemuro area of Hokkaido, most masu salmon are landed by trap-nets in May and June.

In the coastal areas of North Korea, catches of masu salmon are made by trap-nets from February to June, inclusive (Yoshida, 1942).

In southern Sakhalin, trap-nets are the main type of gear used. On the west coast of Sakhalin, the peak of masu salmon fishing is sometime in early June. (Dvinin, 1956.) On the west coast of the Kamchatka Peninsula, masu salmon runs to the estuaries of the rivers are observed from mid-June to mid-July, reaching their peak in early July. They are caught together with herring and other fish by coastal trap-nets. (Semko, 1956.) Masu salmon are very scarce in the Amur River, and are of very little importance to the fisheries (Kuznetsova, 1954).

The fishing season for masu salmon usually overlaps that of pink salmon, but it does have some slight dif-

ferences. Masu salmon are fished a little earlier than pink salmon in southern Sakhalin and on the west coast of Kamchatka. They are also fished a little earlier by the offshore fisheries in the Sea of Japan. However, it is also true that masu salmon are caught along the coast of Japan even after the pink salmon fisheries are closed. This is particularly true of the Pacific coast of Honshu, the southernmost part of the masu salmon range.

It is very difficult to get accurate information concerning catches of masu salmon, because in many cases the catches of masu salmon in Japan and the U.S.S.R. are included in the catch records of pink salmon. This is partly because the fishing season for pink salmon overlaps that for masu salmon and partly because the catches of pink salmon are usually much larger than those of masu salmon.

Handa (1932) estimated the Japanese catch of masu salmon including yamame, the freshwater-type masu salmon, as 5,027 metric tons in the year 1930. Some 3,212 metric tons of this total were landed in Hokkaido. Mihara and Sano (1953) estimated the average annual catch of masu salmon in Hokkaido at 1.2 million fish for the period from 1939 to 1950. It fluctuated between a maximum of 4.05 million fish in 1939 and a minimum of 0.23 million in 1945.¹ Assuming that the average body weight of masu salmon is around 2.5 kg,² the average annual catch of 1.2 million fish can be estimated at 3,000 metric tons. The combined catches of pink and masu salmon in the coastal areas of Japan for the years 1960 and 1961 were recorded as 3,000 and 2,000 metric tons, respectively. With the exception of the area surrounding Hokkaido, catches made in the coastal waters of Japan contain more masu than pink salmon. Taking these points into consideration, the annual catch of masu salmon in Japan can safely be estimated to be in the order of a few thousand metric tons per year in recent years.

Landings of masu salmon in the Far Eastern areas of the U.S.S.R. are between 800 and 1,000 metric tons (Semko, 1956). In southern Sakhalin, landings of masu salmon have never exceeded 200 metric tons, even in good years (Dvinin, 1954). Masu salmon catches on the west coast of Kamchatka are less than 20 or 30 metric tons (Semko, 1956). These catches are far less than that for Hokkaido. Records of masu salmon caught in the Primorskaia area by Japanese

¹ It is assumed that decrease in fishing effort as a result of the war affected the catch in this year.

² This figure is often used as a conversion factor for Hokkaido masu salmon and it fits well to the data in Table 3.

TABLE 1. Catch of masu salmon by Japanese fishermen and the number of fishing lots operated by the U.S.S.R. and Japan in Primorskaia (from Taguchi (1957) and statistical records of operations, Association of Russian Territory Fisheries).

Year	Number of fishing lots			Catches by Japanese fishermen (in metric tons)
	U.S.S.R.	Japan	Closed	
1925	6	14	1	37.8
1926	6	14	1	234.4
1927	3	13	0	106.0
1928	2	13	0	179.2
1929	32	22	1	207.0
1930	49	18	1	319.4
1931	43	16	4	179.1
1932	44	12	7	210.0
1933	55	14	0	62.0
1934	55	14	0	170.4
1935	82	12	2	295.1
1936	82	11	3	167.6
1937	82	4	10	7.1
Average for 13 years				167.3

fishermen in the pre-war era are available (Table 1). This table shows that the annual catch for the 13-year period between 1925 and 1937, inclusive, fluctuated between 7.1 and 319.4 metric tons. The catch in these years averaged 167.3 metric tons. Records of catches made by U.S.S.R. fishermen are not available for the same period. However, judging from the ratio of the number of fishing lots operated by Japanese and Soviet fishermen and the ratio of the standard fishing quota³ assigned to each country, it is assumed that in the 1930's catches by Soviet fishermen were equal to or greater than those of Japanese fishermen.

In North Korea, most landings of pink salmon and masu salmon are made in North Hamkyong. Pink salmon are predominant in these landings and the catches of masu salmon are considered to be very small (Yoshida, 1942)⁴.

³ This is the maximum amount of fish that could legally be landed in each unit of the fishing area. The total quota was almost equally shared by Japan and the U.S.S.R. in the early 1930's, but later the quotas for the Soviet fishermen were about twice those for the Japanese fishermen.

⁴ Yoshida stated that the total value of landings of masu salmon was 17,000 yen and the average price per fish in those days was about 3 yen. Therefore, it is estimated that 6,000 fish were caught. According to Yoshida's data, the average total length of masu salmon caught in North Korea was 58.5 cm (see 2.1.5) and this value corresponds to a body weight of about 3.0 kg. If we apply this average, 6,000 fish is equivalent to 18 metric tons.

In the Sea of Japan, fairly good catches of masu salmon are made by offshore gillnet fisheries, while offshore fisheries in the North Pacific yield very few masu salmon. However, no information on the sizes of landings made by the offshore fisheries in the Pacific is available.

2. LIFE HISTORY

2.1 SPAWNING MIGRATION

2.1.1 *Timing.* Masu salmon first appear in coastal areas in spring and migrate upstream until fall, when they spawn in the upper reaches of streams. The timing of this migration varies considerably according to the area.

In Hokkaido, good coastal catches are made in mid-May and continue until late June. Upstream migration of masu salmon starts in May with a peak in July and August. (Ono, 1933.) There is a tendency for migration to take place somewhat earlier in the north than in the south. In the Nishibetsu and Shibetsu Rivers, which drain into Nemuro Strait, upstream migration of masu salmon is usually first observed in May, while in the Shinsha River, which drains into the Sea of Japan, migration starts in mid-June or later and is over by the end of July. (Sano, 1947.) On the Japan Sea coast of Ishikawa Prefecture, Honshu, the fishing season for the coastal longline fishery is from late February to mid-April. The number of fish taken by coastal trap-nets reaches a peak in March and April. Upstream migration of masu salmon in this area occurs between February and June. (Tabata *et al.*, 1959.) On the Pacific coast of Iwate Prefecture, Honshu, at least some catches of masu salmon are, with the exception of the winter months, recorded throughout the year. The largest catches are recorded in May, June and July. A second, smaller peak occurs in September. Upstream migration of masu salmon to the Ozuchi River seems to be around August and September. By late October, when the upstream migration of chum salmon starts, very few masu salmon are present.

In Sakhalin, masu salmon appear on the west coast of southern Sakhalin in mid and late May. They are most abundant in June and are usually present until early July. Almost as soon as they appear in the coastal waters, they start their upstream migration into the rivers. This migration reaches a maximum between mid-June and early July and is finished in early August. (Dvinin, 1956.) In general, the timing of the spawning migration of masu salmon is earlier than that of other species of salmon in the area (Dvinin, 1952).

Along the northern Hamkyong coast of North Korea, masu salmon are caught by trap-nets from February to June. Upstream migration starts in April, as soon as the ice on the rivers breaks up. The biggest migration goes into the Tumen River. Landing of masu salmon at Tori, located in the lower part of this river, starts in early April, reaches its peak in May and continues through June. (Yoshida, 1942.) Pravdin (1949) reported that in the Posetskaia area, which is close to the boundary of Korea, upstream migration is observed in September.

In the Amur River, masu salmon are present before other species of salmon. They usually start their upstream migration in this river somewhere between mid-May and early June after the ice has broken up. In the lower part of the Amur River, the peak of upstream migration occurs sometime in mid-July. Migration is completed by late July or early August. (Pravdin, 1949.)

On the west coast of Kamchatka, upstream migration of masu salmon occurs at least from the Bolshaia River to the Icha River. Catches of masu salmon by coastal trap-nets are made earlier than those of other species of salmon in the area. Runs into the estuary area take place between mid-June and mid-July and are at a peak in early July. (Semko, 1956.)

The areas in which runs of masu salmon are observed are listed as follows, according to the timing of occurrence of the runs: Japan Sea coast of Ishikawa Prefecture (Honshu) and North Hamkyong (Korea)—upstream migration completed by the end of June; Hokkaido, Sakhalin, Amur River and the west coast of Kamchatka—peaks in June and July; Pacific coast of Iwate Prefecture (Honshu)—upstream migration in August and September. The Iwate Prefecture also has the latest spawning runs of chum salmon, runs usually occurring as late as December or January.

2.1.2 Water temperature. The water temperature observed in coastal waters during the season of masu salmon spawning runs varies from approximately 5° to 12°C in Hokkaido (Ono, 1933) and from 7° to 12°C, with an average of 9° to 10°C, on the west coast of Kamchatka (Semko, 1956). These ranges of water temperature in coastal waters where masu salmon are present agree with the range of water temperature observed in offshore areas where masu salmon are distributed. In the offshore gillnet fishing areas in the Sea of Japan, most masu salmon catches are made when the surface temperature is between 8°C and 12°C. The best catches are usually made when the surface temperature is approximately 10°C. (See 2.6.1.)

In Hokkaido, the Shinsha River, which drains into the Sea of Japan, has a water temperature between 15°C and 18°C at the time of masu salmon spawning migration (Sano, 1947). In general, the water temperature in streams of Hokkaido reaches as high as 15°–20°C in August. It is expected that a fairly high water temperature might be observed in the Ozuchi River of Iwate Prefecture during upstream migration in the months of August and September as this small stream has rather little flow. On the other hand, it is considered that the water temperature in streams of North Korea would be fairly low during the migration period since migration occurs right after the break-up of ice.

2.1.3 Maturation. At the time of commencement of upstream migration, masu salmon are not yet quite mature. In general, masu salmon feed in freshwater streams, although some fish migrating up certain streams in southern Hokkaido do not eat at all after entering fresh water (Sano, 1947). For fish caught in offshore areas of the Sea of Japan, the proportions of gonad weight to body weight were 3% for females and 0.4% for males in May (Jap. Sea Reg. Fish. Res. Lab., unpub.), while for fish caught in the same month near Okujiri Island off the west coast of Hokkaido these proportions were 2.5% for females and 1.2% for males (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956). The proportions of gonad weight to body weight for fish sampled from the Shinsha River on the Japan Sea coast of Hokkaido were 1.7% for females and 0.5% for males in June (Table 10). The proportion of gonad weight to body weight for fish sampled in June on the west coast of southern Sakhalin was reported to be between 0.4% and 1.0% with an average of 0.7% for males. Female fish had more developed gonads. (Dvinin, 1952.) Dvinin (1956) also reported that the proportions of gonad weight to body weight for masu salmon of coastal runs are, on an average, 0.9% for males and 3.8% for females. Semko (1956) reported that the gonad weight of females from coastal waters along the west coast of Kamchatka varied between 7% and 9% of the body weight. In the spawning season, the gonad weight makes up about 20% of the body weight for females and 5% or more for males (see section 2.2.2). These data indicated that most of the development of gonads in masu salmon is made after the fish enter the streams.

When masu salmon are in the streams, their gonads gradually develop. They eventually stop feeding and certain changes become evident in their appearance. Masu salmon which were taken in the Shinsha River at the end of June for a feeding experiment showed no differences in their appearance from those observed in

the sea. However, by late July, some change in the body surface was observed and, in mid-August, secondary sexual characteristics were noted. (Sano, 1947.) During spawning, the body surface becomes covered with black and vermilion stripes. This coloration, as is the case with other secondary sexual characteristics, is more marked in males than in females.

2.1.4 Age at maturity. It is generally accepted that most masu salmon reach maturity in their third or fourth year of life⁵. In Hokkaido, more than 90% of the masu salmon spend one winter in fresh water and one winter in the ocean. All of the remaining fish spend two winters in fresh water and one winter in the ocean. (Sano, 1951, 1959.) The age composition of masu salmon on the west coast of South Sakhalin is similar. Three-year-old fish are predominant and four-year-old fish are rare. The proportions of four-year-old fish in the runs in 1948, 1949 and 1950 were 1%, 11% and 22%, respectively (Dvinin, 1952). Semko (1956) stated that the ocean growth of masu salmon from streams in West Kamchatka is slower than that of coho salmon. Masu salmon originating from West Kamchatkan streams usually spend two winters in the ocean. Their age composition is as given in Table 2. This age composition is quite different from that for fish from Hokkaido and South Sakhalin. On the other hand, Krykhtin (1958) suggested that some fish from streams along the west coast of Sakhalin may spend two winters in the ocean. He did not observe any fish which had spent two or more winters in fresh water.

Both one-winter and two-winter-in-freshwater smolts are represented in samples collected in freshwater streams and from downstream migrants; however, most of the fish in the samples are one-winter-in-freshwater smolts (see section 2.5.1).

Although there are some exceptional cases, such as those reported by Semko (1956) and Krykhtin (1958), Birman (1953) stated that most masu salmon spend one or two years in fresh water and one year in the ocean and that the basic maturing age for masu salmon is 3₂. From his statement, it is assumed that most masu salmon originating in U.S.S.R. streams reach

TABLE 2. Age composition of adult masu salmon in streams of West Kamchatkan areas (from Semko, 1956).

Stream	Age composition (in no. of fish)				Total
	3 ₂	4 ₂	4 ₃	5 ₃	
Kolpakovskaia River	4	12	—	4	20
Utka River	—	16	2	6	24

maturity at age 3₂. Considering the fact that the west coast of Kamchatka is the northern limit of the geographical distribution of masu salmon, it is not surprising that those bound for this area spend two winters in the ocean. However, another thing which should be noted is that some scales have an intermediate band on the boundary between the freshwater growth zone and the marine growth zone. In addition, there are two types of scales—one which does and one which does not have an annulus in its marine growth zone. (See section 4.5.1.) The differences observed in the ages of maturing or matured fish could be attributable to inconsistencies inherent in the aging technique rather than to geographical variations.

2.1.5 Fork length and body weight. The size of masu salmon migrating to coastal waters varies from a minimum fork length of 40 cm (weighing less than 1 kg) to a maximum of about 70 cm (about 9 kg). This is very interesting, because most pink salmon are considered to spend just one winter in the ocean and in this case their size is very consistent. Probably, this significant variation in the size of masu salmon according to area can be attributed to the great variations in the marine environments which they occupy.

Ono (1933) reported that the body length of masu salmon in coastal waters of Hokkaido ranged from 40 to 50 cm. Handa (1932) and Akiba (1936) gave size data which are reproduced here in Table 3. In Table 4, the mean standard lengths are given for masu salmon sampled in various streams of Hokkaido (Sano, 1951). In Table 5, the sizes of masu salmon reported by Dvinin (1956) and Semko (1956) for various Far Eastern areas are given. Yoshida (1942) reported that the total length of the masu salmon sampled in the Tumen River and from the Japan Sea coast of North Korea in late May of 1939 varied from 44.5 to 74.0 cm and averaged 58.5 cm.

From these data, it is concluded that the masu salmon from Sakhalin and Kamchatka are small, those from the Amur River, Primorskaia and North Korea are large and those from the streams of Hokkaido are generally large, with some variations according to

⁵ Age designations used in this paper conform with those used in other parts of the INPFC comprehensive report on salmon; i.e., a fish in its third year of life is called a "three-year-old". To designate freshwater and ocean ages, a three-year-old which migrated to sea in its second year of life and has spent one winter in the ocean is called a "3₂" fish. Soviet authors generally use a system of age designation by which a three-year-old is called a "2+" fish, four-year-olds, "3+", etc.

TABLE 3. Total length¹⁾ and body weight of adult masu salmon in the streams of Hokkaido.

Stream	Sex	Total length		Body weight		Source
		Range	Mean	Range	Mean	
		cm	cm	kg	kg	
Shiribetsu R.	Female	39.6-64.4	55.4	1.913-3.553	2.550	Handa (1932)
	Male	36.3-57.8	48.8	1.538-3.131	2.325	Handa (1932)
Nishibetsu R.		46.2-74.3	57.1	1.200-4.163	2.138	Handa (1932)
Chitose R.		50.0-71.0	62.7	1.5-5.1	3.4	Akiba (1936)

¹⁾ In the data given by Handa, length is designated as body length. However, it is assumed that this means total length. In the case of masu salmon, there is not much difference between fork length and total length.

TABLE 4. Standard length of adult masu salmon in the streams of Hokkaido (from Sano, 1951).

Stream	Sample size (in no. of fish)	Sampling period	Mean standard length ¹⁾
			cm
Chitose R. (Japan Sea)	52	1946 IX-X	48.1
Shinsha R. (Japan Sea)	190	1946 VII-VIII	47.0
Shubuto R. (Japan Sea)	96	1946 VIII-IX	46.0
Tokoro R. (Okhotsk Sea)	196	1946 VII-IX	45.5
Shari R. (Okhotsk Sea)	52	1946 VI-VIII	45.3

¹⁾ The ratio of standard length to fork length is not clear. However, it is believed that fork length is five or six percent longer than standard length.

TABLE 5. Size of adult masu salmon in various Far Eastern areas of the U.S.S.R.

Area	Sex	Body length ¹⁾		Body weight	
		Range	Mean	Range	Mean
		cm	cm	kg	kg
West coast of South Sakhalin (1947-1953)	Male	34-55	46.6	0.6-2.7	1.35
	Female	34-54	45.5	0.6-2.4	1.4
West coast of Kamchatka					
Kolpakovskaia R.			44.0		1.3
Utkha R.			46.2		1.48
Downstream of Amur River	Male	46-67	56.8	1.8-3.2	2.3
	Female	47-62	54.4	1.6-3.1	2.3
Poset (at the border of Korea)	Female	52-68	61		
Tumnin R. (Strait of Tartary)	Male	-71	63	-6.0	4.0

¹⁾ Although it is not indicated what standard was applied for measuring length, it is probably fork length.

TABLE 6. Yearly variations in the size of masu salmon in southern Sakhalin.

Year	Sex	Mean body length ¹⁾	Mean body weight
		cm	kg
1948	Male	43.7	1.4
	Female	43.9	
1949	Male	49.2	1.6
	Female	47.2	

¹⁾ Probably fork length.

individual rivers. Dvinin (1952) described yearly variations in the size of masu salmon in southern Sakhalin (Table 6).

Although the masu salmon runs to Hokkaido contain some 4₃ fish as well as 3₂ fish, the run can still be considered to consist of a uniform age group because of the dominance of the 3₂ age group. The mean fork length of each age group of masu salmon sampled from the Amur River is given in Table 7. Spawning migrations of masu salmon to southern Sakhalin and the

TABLE 7. Mean fork length by age of masu salmon collected in the Amur River (from Pravdin, 1949).

Sex	Age ¹⁾			
	1-year-old	2-year-old	3-year-old	4-year-old
	cm	cm	cm	cm
Male	12.7	31.5	65.0	—
Female	15.5	36.6	56.2	58.8

¹⁾ The age in fresh water is not given in Pravdin, 1949.

west coast of Kamchatka consist of many different age groups. The fork length and body weight of each of the age groups participating in the migration are presented in Tables 8 and 9.

2.1.6 *Sex ratio.* Generally, females dominate numerically among masu salmon which have returned from the sea. This observation contrasts markedly with the dominance of males among yamame, the freshwater-type masu salmon.

Ono (1933) reported that the proportion of females in the samples of mature fish collected along the Pacific coast of Hokkaido ranged between 52% and 83%. It is also reported that the proportion of females in the samples of mature fish from the Shiribetsu River, Shubuto River and Chitose River were 73%, 76% and 66%, respectively. These three rivers all drain into

the Sea of Japan. The proportion of females in similar samples from the Nishibetsu River, which empties into Nemuro Strait, was 64%. From 60% to 71% of the masu salmon caught in Hokkaido streams between 1948 and 1957, inclusive, for artificial hatchery work were females. The ten-year average was 63%. According to Saguri (1936), one sample collected in a river in Toyama Prefecture consisted of 57 females (78%) and 16 males (22%). He also stated that similar samples from the Tedoru River in Ishikawa Prefecture and from the Kuzuryu River in Fukui Prefecture consisted of 98.3% females and 99% females, respectively.

Dvinin (1952) reported that only 10 males were present in a sample of 100 fish taken in August from the Raichisi River on the west coast of Sakhalin. He also stated that the proportion of males in catches of masu salmon taken in early June can be as high as 25% of the total. Semko (1956) reports that approximately 60% to 70% of the total catch of masu salmon in the Utka River on the west coast of Kamchatka was female.

This predominance of females in masu salmon stocks can also be observed in smolts migrating downstream and smolts which have just entered the sea (see section 2.5.2). This unbalanced sex ratio occurs throughout the marine stage of the life cycle (see section 2.6.4).

TABLE 8. Size of adult masu salmon in southern Sakhalin by age (from Krykhtin, 1958).

Age ¹⁾	Sex	Body length ²⁾		Body weight	
		Range	Mean	Range	Mean
		cm	cm	kg	kg
3 ₂ (Spring downstream migrants)	Male	44-57	49.7	0.9-2.9	1.595
	Female	45-55	49.6	1.2-2.3	1.628
3 ₂ (Summer downstream migrants)	Male	37-49	45.0	0.5-1.7	1.228
	Female	35-50	46.1	0.5-1.8	1.388
4 ₂ (Fall downstream migrants)	Male	47-60	53.6	1.3-3.0	2.022
	Female	49-59	53.3	1.5-3.0	2.094

¹⁾ See sections 2.1.4 and 2.5.1 for ages.

²⁾ Probably fork length.

TABLE 9. Size of adult masu salmon of the west coast of Kamchatka by age (from Semko, 1956).

Stream	3 ₂		4 ₂		4 ₃		5 ₃	
	Body length ¹⁾	Body weight	Body length ¹⁾	Body weight	Body length ¹⁾	Body weight	Body length ¹⁾	Body weight
	cm	kg	cm	kg	cm	kg	cm	kg
Kolpakovskaia R.	38.5	0.910	44.9	1.380	—	—	46.1	1.475
Utka R.	—	—	47.1	1.520	38.0	0.775	47.0	1.575

¹⁾ Probably fork length.

In contrast, in the case of yamame, the freshwater-type masu salmon, it is believed that males are dominant (see section 2.7).

2.2 SPAWNING

Masu salmon migrate upstream in summer and early autumn. They feed for a time in fresh water while their gonads are maturing, but once matured the fish stop feeding. They spawn in the fall near the headwaters of the streams. Their spawning ecology is similar to that of other species of the genus *Oncorhynchus*. The depth of the water in the best spawning grounds is about one to two feet. Masu salmon dig a nest in the gravel on the spawning bed. The eggs, which are approximately 0.7 cm in diameter, are deposited in the nest. On occasion, matings between males of yamame and females of masu salmon have been observed. All masu salmon without exception die after spawning. (Ono, 1933; Sano, 1947.)

Masu salmon spawn near the headwaters of streams and seem to tend to spawn further upstream than chum salmon (Handa, 1932). In the Amur River, some migrate as far as 300 or 400 km upstream from Nikolaevsk (Pravdin, 1949).

2.2.1 Spawning period. The spawning period varies according to the area. In Hokkaido, spawning takes place from early September to mid-October (Sano, 1947). The spawning period of masu salmon in Ishikawa Prefecture is also from September to October. The carcasses of spent fish are found in late October. (Tabata *et al.*, 1959.)

Spawning in the rivers of Sakhalin occurs from the last half of July to early September. The main spawning ground in the Raichisi River in Sakhalin is located in the upper part of the river. (Dvinin, 1952, 1956.) Although the exact locations of spawning areas along the west coast of Kamchatka are not as yet well known, a few mature masu salmon are occasionally observed in mid and late August in the lower as well as the upper Bolshaia River (Semko, 1956).

2.2.2 Maturation in the river. Some masu salmon collected in the Shinsha River in late June were kept in experimental enclosures in order to observe changes in body and gonad weights (Sano, 1947). During the first month after collection, the body weight decreased rather rapidly. Then the rate of decrease gradually slackened as a result of the initiation of rapid gonad development. However, if the gonad weight is subtracted from the total body weight, then the resulting weight continued to show a marked decrease in the second month. These resultant weights were only 55% for females and 68% for males of what they had been at the time of capture. The monthly changes in the proportion of gonad weight to total body weight observed during this experiment are given in Table 10. It might be considered that the fish have matured completely by September. Semko (1956) observed that the proportion of gonad weight to total body weight for female masu salmon taken in the downstream part of the Utka River was 20.6% for females of age 4₂ and 16.3% for those of age 5₃.

2.2.3 Fecundity. There are remarkable differences in fecundity in different rivers. It is reported that 2,500 eggs is the mean fecundity, or average number of eggs spawned per female, for masu salmon spawning in Hokkaido (Handa, 1932; Ono, 1933). A fecundity of 3,000 to 4,000 eggs per female salmon is also reported (Sano, 1950). Information on the fecundity of masu salmon collected in various rivers and in coastal waters is presented in Table 11.

The number of eggs taken per female in the Hokkaido hatcheries varied, according to the egg-taking

TABLE 10. Monthly variations in the proportion of gonad weight to total body weight for masu salmon of the Shinsha River (from Sano, 1947).

Sex	June	July	Aug.	Sept.
Male	0.53%	5.8%	6.4%	6.5%
Female	1.68	7.4	23.9	26.8

TABLE 11. Fecundity of masu salmon in Hokkaido, Honshu and the Sea of Japan.

Area	Fecundity		Mean body weight	Source
	Range	Mean		
			kg	
Nishibetsu R. (Nemuro Strait)	1,172-3,602	2,720	2.1	Handa (1932)
Chitose R. (Japan Sea)	1,968-5,362	3,822	3.4	Akiba (1936)
Sho R. Toyama Pref. (Japan Sea)	3,069-5,434	4,051	2.5	Saguri (1938)
Near Okujiri Is. (Japan Sea)	1,230-2,937	2,040	1.0	Hokk. Pref. & Reg. Labs. (1956)
Sea of Japan	1,800-5,700	3,244		Data provided by Japan Sea Fish. Lab.

TABLE 12. Fecundity of masu salmon in the Far Eastern regions of the U.S.S.R.

Area	Age	Fecundity		Source
		Range	Mean	
South Sakhalin		739-2,683	1,900	Dvinin (1956)
South Sakhalin	3_2 (Spring)	1,145-2,745	1,675	Krykhtin (1958)
	3_2 (Summer)	520-1,820	1,352	
	4_2 (Fall)	1,225-3,059	2,237	
Amur River		1,386-3,261	3,200	Dvinin (1956)
West coast of Kamchatka				
Kolpakovskaia R.			2,025	Semko (1956)
Utkha River			3,700	

TABLE 13. Variation of fecundity of masu salmon by size of fish (from Semko, 1956).

Stream	Ranges of body length		
	45.0 cm or less	45.1-47.0 cm	47.1 cm or more
Kolpakovskaia R.	1,910	2,080	2,507
Utkha River	3,520	3,830	3,850

records of various hatcheries for 1934 and 1935, from a minimum of 1,270 to a maximum of 3,330 (Akiba, 1936). Differences in the number of eggs taken per fish might depend partly on egg-taking techniques as well as on fish condition. However, it should be noted that at the central hatchery, which is on the Chitose River, averages of 3,300 eggs and 3,100 eggs were taken per female in 1934 and 1935, respectively. As is indicated in Table 11, the masu salmon on the Chitose River do have a high fecundity. For masu salmon collected in the Shiribetsu and the Shubuto River systems, which drain into the Sea of Japan, the number of eggs per female are given respectively as 2,300 to 3,300 and 2,500 to 2,600. In contrast, the fecundity given for masu salmon taken from the streams which drain into the Okhotsk Sea is only 1,500 to 2,000 eggs. It is not known whether these differences in the number of eggs taken per female are reliable enough to accurately represent the variations in the fecundity between the different rivers. In the hatcheries of Hokkaido, the average number of eggs taken per female masu salmon during the ten-year period from 1948 to 1957, inclusive, was 2,048 (Sano, 1959). With female chum salmon, it has been found that the ratio of the average fecundity to the average number of eggs taken by the hatchery is 3,000 to 2,629. When this conversion factor is used for the masu salmon of Hokkaido, then the 2,048 egg ten-year average for the hatcheries represents a fecundity of 2,340 eggs per female. Judging from this, the value 2,500 given by Handa (1932) and Ono (1933) as the average fecundi-

ty of the masu salmon in Hokkaido seems to be reasonable. In Table 11, the Sea of Japan category (including the area adjacent to Okujiri Island) might include masu salmon which are not bound for Hokkaido.

The fecundity of masu salmon from the Far Eastern areas of the U.S.S.R. is given in Table 12. The big difference in fecundity between fish of the Amur River and those of the west coast of Sakhalin is correlated with the difference in body size of fish collected in these two areas (Dvinin, 1956). Some variations in fecundity by age and fork length are found for masu salmon on the west coast of Kamchatka. In Table 13, the masu salmon from West Kamchatka have been divided into three size ranges according to fork length and for each the average fecundity is given. (Semko, 1956.) Kuznetsova (1954) counted the number of ova in the gonads of masu salmon smolts collected in the Amur River and in the streams of Primorskaia and reported counts of 3,364 to 6,310 for fish from the Amur River and 2,729 to 7,218 for those from Primorskaia. The average value for fish from the Amur River was 5,000; for those from Primorskaia it was 4,550. These values are considerably higher than the counts of eggs in mature fish. As these counts are for smolts, some of the ova may not develop into mature eggs.

When geographical variations in fecundity are compared with geographical variations in size of fish, some relationships are found to exist. The low fecundity of most fish from Sakhalin and Kamchatka is related to the smaller fish size, with the exception of Utkha River masu salmon which have a considerably higher fecundity. The high fecundity of fish in the Amur and Chitose Rivers is in turn related to larger fish size. In Hokkaido, it is said that areal variations which were once seen in the fecundity of masu salmon have been greatly reduced in recent years because of the many artificial transplants.

No information is available as to the proportion of eggs in the gonad actually spawned at spawning time. However, it seems feasible to assume that most of the eggs would be spawned.

2.3 HATCHING

Under a constant water temperature of 8°C, the temperature of the spring water used in many hatcheries, masu salmon eggs reach the eyed stage at the end of the fourth week after spawning and hatch out after 55 to 60 days. However, eggs laid in natural streams seem to take more time. In some cases, they are known to take as long as three months. (Ono, 1933.) In one series of experiments, fertilized eggs were taken from yamame (freshwater-type masu salmon) which had been caught in a stream tributary to Kizaki Lake, Nagano Prefecture. They were hatched under various water temperatures and it was found that for water temperatures between 7°C and 11°C there was a high rate of survival to hatching accompanied by a very low abnormality rate. (Kawajiri, 1927.) In cases where the water temperature was kept below 3°C, 100% mortality took place. At approximately 6°C, 85 to 90 days elapsed between the time the eggs were laid and the time that they hatched. At approximately 10°C, the time required was about 50 days and at about 14°C, it was approximately 35 days.

After hatching, the fry stay in the gravel until some time between the end of April and the end of May. When the fry emerge from the gravel they are about 3 cm in length and have parr marks. At this stage, they all resemble yamame, the freshwater-type masu salmon. The sex ratio of these fry is almost 1 to 1. (Ono, 1933.) An average hatching rate of 87% was observed in the Hokkaido hatcheries during the years 1948 to 1957, inclusive. This rate was identical to those of chum and pink salmon.

2.4 FRESHWATER LIFE

As is the case with coho salmon, masu salmon fry usually stay in fresh water for one or more years after emergence from the gravel. During the first summer after hatching, masu salmon fry feed in the streams and grow very rapidly. After spending one winter in fresh water, most of them migrate downriver to the sea in the following spring. A few of them remain in freshwater streams for another winter. A considerable proportion of the males and a very small proportion of the females remain in fresh water for their entire lives. These fish mature and complete their life cycle in fresh water.

2.4.1 *Growth.* After emerging from the gravel

beds, the fry feed greedily and in Hokkaido they grow to 8 or 10 cm or more in length by the following summer (Ono, 1933; Sano, 1950). It is assumed that the growth rates might vary considerably in accordance with the environments of individual streams. For example, Dvinin (1952) reported that the average body length of masu salmon fry collected in the Kalinka River on the west coast of Sakhalin on May 21, 1946, was 11 cm. The body lengths varied from a minimum of 8.6 cm to a maximum of 14.8 cm. The body weights of these fry ranged from 6 to 39 grams with an average of 13 grams. In comparison, fry collected in the Raichisi River on August 1 of the same year averaged 9.4 cm in body length and ranged from 7.3 to 17.0 cm. They averaged 13 grams in body weight and varied from 4 to 24 grams. However, the former range of 8.6 to 14.8 cm in May is a little doubtful as the values seem to be unusually large for fry that have emerged in the same year. It is suspected that this sample from the Kalinka River may be from smolts which had already spent one winter in the stream.

According to Kuznetsova (1954), the range of fork lengths for fry sampled in various rivers along Primorskaia was 4.9 to 15.8 cm, with an average of 9.4 cm. This included one-, two- and three-year-old fish (0+, 1+ and 2+). She also reported that the fry sampled from the Amur River during May and June ranged from 8.1 to 15.0 cm in length, with an average of 11.0 cm. These samples included two- and three-year-old fish (1+ and 2+). The mean fork length for two-year-old fish in a sample taken in one Primorskaia stream during May was 11.2 cm. The average fork length for a sample taken in the same area, but from a different stream, in September was 12.0 cm and that for a December sample taken in the same area, but again from a different stream, was 11.5 cm. The average for a sample taken between May and July in the Amur River was 11.0 cm.

In the fall, the growth rate slows down remarkably. In winter, fry in most areas (except some with relatively high water temperatures) hardly feed at all and as a result there is little or no growth. They spend the winter in areas where springs occur or in the deep and quiet portion of the river. During this period the first annulus is formed on the scale. (Ono, 1933; Sano, 1950.) The fork length at the time of formation of the first annulus has been back-calculated for masu salmon from various areas of the U.S.S.R. (Table 14). Some errors could have resulted because of the problems inherent in reading scales. However, it seems feasible to assume that the size of the smolts which would migrate down to sea in the spring after spending one

TABLE 14. Estimated body length computed from the growth of scales of masu salmon in the Far Eastern areas of the U.S.S.R. at the time of formation of first and second annuli in the freshwater growth zone and at the time of downstream migration.

Area	Ages of specimens	Estimated size ¹⁾			Source
		First annulus	Second annulus	Time of seaward migration	
		cm	cm	cm	
WEST COAST OF SAKHALIN :					
Antonovo (ocean)	2-year-old smolts	11.1			} Dvinin (1952)
	Adults	12			
Ainskaia R., Novoselovskaia R., Kholmsk (ocean) —combined	Adults 3 ₂ , Spring	10.1		12.0	} Krykhtin (1958)
	Adults 3 ₂ , Summer	8.0		11.3	
	Adults 4 ₂ , Fall	6.3		11.7	
Ainskaia R.	2-year-old downstream migrants, Apr. 22	10.0		11.5	
	„ Aug. 3	7.1		11.9	
	„ Sept. 1	5.2		10.7	
WEST COAST OF KAMCHATKA :					
Kolpakovskaia R.	Adults 3 ₂	10.5		11.8	} Semko (1956)
	Adults 4 ₂	10.1		12.5	
	Adults 5 ₃	8.8	13.6	14.2	
Utka River	Adults 4 ₂	10.9		12.0	
	Adults 5 ₃	8.8	13.3	14.3	
PRIMORSKAIA :					
Kedrovka R.	2-year-old smolts, May	10.4		11.2 ²⁾	} Kuznetsova (1954)
Nelma R.	„ Sept.	8.0		12.0 ²⁾	
Bolshaia Elduga R.	„ Dec.	7.8		11.5 ²⁾	
AMUR RIVER :					
Khivanda R.	2-year-old smolts, May-July	9.6		11.0 ²⁾	

¹⁾ Probably fork length.

²⁾ Actual fork length of specimens.

winter in fresh water is about 10 to 11 cm in fork length at the time of formation of the first annulus, while the size of the fish which would migrate down to sea in or after the summer, or after spending two winters in fresh water, appears to be less than 9 cm in fork length at the time of formation of the first annulus. Regardless of the time of year at which seaward migration occurs, fish that migrate downstream after one winter in fresh water are about 11 or 12 cm long and those which migrate after two winters in fresh water are approximately 14 cm long by the time of their downstream migration. The masu salmon in Hokkaido exhibit a little better growth while in fresh water than those listed in Table 14.

2.4.2 Feeding habits. Masu salmon are carnivorous while in fresh water. Sano (1950) reported that they feed, just after their emergence, on micro-organisms, small crustaceans and other invertebrates. In late spring and early summer, they feed mainly on insects. A more detailed description of food items is not given in the paper. During September and October, the

amount of food they take gradually decreases until by November they have almost stopped feeding. Kuznetsova (1954) observed that, in Primorskaia and the Amur River, a significant part of their food consists of aerial and terrestrial insects, in addition to the benthonic animals. In these areas, the aerial and terrestrial insects are the main food from June to September, while during the winter and early spring the benthonic animals are the most important. No plankton are eaten by young masu salmon. In their second year of life in fresh water, masu salmon smolts start to feed on fish as well, primarily salmon fry. Their stomachs are usually almost full during the period from May to September, but from then until the early part of the following spring, when insects become more abundant, the amount of food in the stomach decreases. For example, stomach content in December is about one-third of that in May and June.

2.4.3 Maturation. Some of the males show signs of sexual maturity before their first winter in fresh water. The gonads of some of them are fairly well

developed and may even give up a quantity of milt. By this time the bodies of these fish have started to assume the dark spawning coloration. It is thought that these males never make any downstream migration. No females become ripe in their first year. (Ono, 1933; Oshima, 1957.) According to Kuznetsova (1954), the ovaries and testes of masu salmon fry can be easily differentiated even with the naked eye.

2.5 SEAWARD MIGRATION

Parr marks on masu salmon smolts disappear and the fish become a silver color in the spring following their first winter in fresh water. These changes occur at the beginning of their seaward migration, at a time when the fish are doing considerable feeding. At this stage in their development, the fish are often called "ginke (silver fur)". Migration seems to be especially active from sunset until early morning. Generally, smolts migrate downstream after spending one winter in fresh water. However, some spend two winters in fresh water. Both sexes participate in the downstream migration, but females are much better represented than males. The gonads of these fish are immature. The smolts are caught by trap-nets in coastal waters for a short time after they enter the sea, but

then they leave for offshore waters and are no longer caught. Some smolts, especially males, remain in fresh water throughout their lives and never lose their parr marks. This phenomenon will be described further in section 2.7. The silvery smolts which migrate seaward are generally slender and their body depth is less than that of yamame at the same stage in the life cycle. (Ono, 1933.)

2.5.1 Age at seaward migration. Judging from the ages of the smolts and adults sampled in the rivers and coastal waters of Hokkaido, it appears that most masu salmon spend just one winter in fresh water before their seaward migration. A very few spend two winters in fresh water before migrating. Some data on the age at seaward migration are given in Table 15. Kawakami's data (1937a) also indicate that 96.8% of the smolts of masu salmon taken in coastal waters had spent one winter in fresh water (Table 16).

In the feeding experiments, about two-thirds of the masu salmon smolts lost their parr marks after spending one winter in fresh water (Fujita, 1933; Saguri, 1936). Most of the remaining fish would spend the rest of their lives in the rivers and only a small proportion of them would ever migrate to sea. Kuz-

TABLE 15. The frequency and percentage of one- and two-winter-in-freshwater fish in the samples of smolts and adults of masu salmon collected in the streams and coastal waters of Hokkaido.

Specimens	Freshwater age				Source
	1-winter		2-winter		
	<i>No. of fish</i>	<i>Percent</i>	<i>No. of fish</i>	<i>Percent</i>	
Downstream migrants, in the stream	36	100.0	—	0	} Ono (1933)
Smolts, in the sea	222	97.4	6	2.6	
Adults, returning into the coastal waters	92	96.8	3	3.2	
<i>Total</i>	<i>350</i>	<i>97.5</i>	<i>9</i>	<i>2.5</i>	
Shubuto R. (Japan Sea), Adults		91.1		8.9	} Sano (1959)
Shinsha R. " "		91.0		9.0	
Chitose R. " "		100.0		0	
Tokoro R. (Okhotsk Sea), "		94.6		5.4	
Shari R. " "		92.4		7.6	

TABLE 16. Sex ratio of masu salmon smolts collected in streams and coastal waters of Hokkaido.

Area of collection	Female		Male		Period of sampling	Source
	No. of fish	Percent	No. of fish	Percent		
Nishibetsu R. and Mitsuishi R.	36	72.0	14	28.0	late May-early June June	Ono (1933)
Along Pacific coasts of Hokkaido	203	78.1	57	21.9		
Coastal waters of Shizunai,					June	Kawakami (1937a)
Hidaka, Hokkaido 2-year-olds	113	90.4	12	9.6		
3-year-olds	4	100.0	—	0		

netsova (1954) reported that the smolts found in the streams of Primorskaia and in the Amur River ranged from one-year-olds to three-year-olds in age. Three-year-old fish were, however, very scarce.

Although there have been differing views on the age of maturity (these could be because of geographical variations), it is generally agreed that fish spend one or two winters in fresh water, with one-winter-in-freshwater fish being dominant (Semko, 1956; Krykhtin, 1958).

2.5.2 Sex ratio. Females are the predominant sex in the seaward migrations. Some data on sex ratios are shown in Table 16. These sex ratios are not very different from those reported for returning adults. In contrast, males are the predominant sex in the case of yamame, which do not go into the ocean. Saguri (1936) reported that three-quarters of the yamame were males. Sex ratios were calculated for different size ranges of yamame which had been collected at various times of the year from the Nishibetsu hatchery on the Nishibetsu River in Hokkaido (Ono, 1930). In samples taken during the period from February through April, two-year-old fish which ranged from 11.0 to 15.0 cm in length were approximately equal in number of males and females. However, the larger fish taken during the same period were all males. Approximately one-half of the fish sampled in May and June which ranged from 7.0 to 11.0 cm in length (assumed to be one-year-olds) were males, while all of the fish ranging between 12.0 and 13.0 cm and collected during the same months were males. Fish in their first year of life collected in the fall had reached a length of 8.0 to 13.0 cm. Males and females were both represented in these samples. However, the two-year-old fish taken in the same season were all males ranging between 17.0 and 18.0 cm in length. From these results, it is concluded that almost all the females which had spent one winter in the rivers migrated to the ocean early the following spring. In contrast, many of the males had stayed in the rivers for at least another year.

2.5.3 Timing. Fujita (1933) reported that smolts which were fed in experimental enclosures lost their parr marks in late March. In experiments carried out by Saguri (1936), some changes in body shape were observed in early May. Both of the abovementioned experiments were conducted in Toyama Prefecture. In Hokkaido, the disappearance of parr marks starts around March or April (Sano, 1950). In the Nishibetsu River in Hokkaido, the fishing grounds for masu salmon smolts migrating to sea shift progressively downstream in late May. Along the Mitsuishi

River in the Hidaka area of Hokkaido, many downstream migrants of masu salmon are trapped in weirs from late May to early June. The period when the downstream migrants are fished by sport fishermen varies according to the geographical area. In general, this time is in late May and early June; however, in some areas fishing occurs as early as April. From these facts, it is assumed that most masu salmon smolts migrate seaward from mid-May to early June. (Ono, 1933.) In an example referred to in Section 2.5.2, on the variation in sex ratios, two-year-old females disappear from the samples somewhere between April 12 and June 2. Another piece of evidence is given by records of the incidental catch of masu salmon smolts by trap-nets set in coastal waters for other species of fish. Some smolts start appearing in the catch in mid and late May. The largest catches are made in early and mid-June and masu salmon have almost disappeared from trap-net catches by July, at which time most of the smolts are considered to have moved to the offshore waters. (Ono, 1933.) In Toyama Bay, some masu salmon smolts about 17 cm in length were caught on April 23 in a trap-net (Saguri, 1936).

Krykhtin (1958) stated that the smolts on the west coast of Sakhalin migrate into the ocean during the fall in September and October as well as in the spring and early summer during April, May and June. According to him, the timing of seaward migration is determined by the amount of growth during the first year of life. Smolts which had grown less in the year just past migrated downstream later in the season. Therefore, all downstream migrants were almost identical in size, ranging from 11 to 12 cm in body length, regardless of the time of migration (Table 14). Dvinin (1952, 1956) stated that young masu salmon stay in coastal waters for a long period after entering the sea and that many of them are accidentally caught during June and July by herring gillnets or coastal trap-nets set along the west coast of southern Sakhalin. Judging from the above information, it seems probable that more smolts go to sea during April, May and June than in the fall. It should be noted that some sport fishermen believe that in Hokkaido some of the young masu salmon migrate downstream in the fall. However, no evidence in support of this belief has as yet been found.

2.5.4 Size. The length of smolts at the time of seaward migration varies according to age as well as according to geographical area. In Hokkaido, the migrants which have spent one winter in fresh water are approximately 15 cm in length. Ono (1933) observed that some of the downstream migrants in the Mitsuishi River in the Hidaka district reached a total

length of about 18 cm. Kawakami (1937a) sampled young masu salmon in mid-June from coastal waters near Shizunai in the Hidaka district immediately after their entrance into the sea. He reported that the total length ranged from 14.8 to 28.0 cm with a mean of 19.2 cm. The weights for these fish ranged from a minimum of 28 grams to a maximum of 198 grams. The mean weight was 67 grams. The silver colored smolts obtained in feeding experiments in Toyama Prefecture were 20 to 25 cm in total length and weighed 70 to 150 grams in early May (Fujita, 1933). The same type of fish obtained from Saguri's experiment were 12 to 19 cm in total length and 18 to 64 grams in weight in early April (Saguri, 1936).

The mean length of fish involved in the downstream migration of masu salmon in Sakhalin was reported to be 11 cm. The individual lengths ranged from 8.5 to 14.7 cm, while the weights varied from 7.0 to 39.0 grams. (Dvinin, 1956.) Scales which had been taken from adult masu salmon collected on the west coast of Kamchatka were used to back-calculate the lengths of the fish at the time that they left fresh water. This value was 12 cm for fish that had spent one winter in fresh water and 14 cm for fish that had spent two winters in fresh water. A one-winter-in-freshwater fish caught on July 21 in the Bolshaia River while migrating downstream was 11.1 cm in length (Semko, 1956). Some other data on the size of downstream migrants in other areas of the Far Eastern region of the U.S.S.R. are shown in Table 14. It is noted that the average length of downstream migrants which had spent one winter in fresh water was about 11 to 12 cm.

It is not clear which measurements were used in recording sizes of downstream migrants in Soviet streams. However, it is assumed that the migrants in Hokkaido and Honshu (Japan) are somewhat larger than those of Soviet streams. This might be because water temperatures in Japan are higher, particularly in the winter.

After they enter the ocean, the growth of young masu salmon is very rapid and as a result the body lengths of fish collected at different times in the same season are often very different. Young masu salmon were sampled in the estuaries along the Urakawa coast of the Hidaka district from late May to mid-June. The females were approximately 15 to 23 cm in body length and the males were about 15 cm (Oshima, 1957). At about the same period of the year, masu salmon of approximately the same size are caught incidentally by trap-nets in Ozuchi Bay in Iwate Prefecture. The body length of these young masu salmon

is about 20 cm (about 25 cm in total length) in July, when most of them leave coastal waters for offshore waters (Ono, 1933). By fall they have grown to as long as about 30 cm in total length. Saguri caught three young masu salmon in Toyama Bay on April 23 (Saguri, 1936). Their total lengths ranged from 17.3 to 17.6 cm and they weighed from 37.5 to 41.3 grams.

On the west coast of southern Sakhalin, young masu salmon which had spent one winter in fresh water were between 13.5 cm and 26.5 cm in body length in June and July. The average body length was 17.0 cm and body weights ranged from 30 to 184 grams with an average value of 74 grams. Specimens collected in November were more than 30 cm in length. (Dvinin, 1956.) Semko (1956) collected some samples in Sakhalin Bay in August and September which were considered to be made up of downstream migrants from the Amur River. He stated that the mean body lengths were 22.2 cm and 26.4 cm for two-year-olds and three-year-olds, respectively. The corresponding average weights were 124 grams and 206 grams.

2.5.5 Feeding habits. Young masu salmon are all carnivorous, although their feeding habits do change when they enter the sea. Downstream migrants are fished very successfully by anglers, as the smolts do considerable feeding during their migration. The appearance and body shape of the young masu salmon which are caught in coastal waters in June are almost identical with those of downstream migrants caught in streams. However, the stomach contents of fish caught in different environments are completely different. In fresh water, the downstream migrants feed chiefly on aquatic insects and to a lesser extent on the eggs and fry of salmonoid fishes. After they enter the sea, they feed actively on Copepoda, Schizopoda, Amphipoda and fry of various fishes. As they grow, their diet changes until it consists mainly of fish. (Ono, 1933.) Kawakami (1937a) noticed that some of the stomachs of young masu salmon sampled in the coastal waters contained freshwater animals as well as marine animals.

Smolts entering the coastal waters of Sakhalin were also observed to feed actively, chiefly on crustaceans and fry of *Pleurogrammus* (Dvinin, 1956). As mentioned earlier, a sample of young masu salmon which had originated in the Amur River was collected in Sakhalin Bay in August and September. These smolts were found to have fed mainly on certain species of fish. At least some fish occurred in the stomachs of all specimens, but in addition, some stomachs contained a small amount of insects and crustaceans.

The fish present in the stomach contents of these masu salmon included smelt, sand lance and herring. (Semko, 1956.)

2.6 MARINE LIFE

Masu salmon feed while migrating in coastal or offshore waters and during this time they grow very rapidly. They generally return to the coasts and rivers after spending one winter in the ocean. It is said that some masu salmon originating in Sakhalin and Kamchatka spend two winters in the ocean. Masu salmon are fished continuously in some areas along the coast of Japan from the time that they enter the ocean as smolts until they leave it to return as adults to their parent streams. Because of this it has been considered that masu salmon must not migrate as far offshore as do other species of salmon. However, the recent development of gillnet fisheries in the Sea of Japan has revealed that the distribution of masu salmon extends over all of the offshore areas of the Sea of Japan. Their wide distribution means that extensive migrations are involved. However, very few masu salmon are caught in the offshore waters of the Pacific Ocean and, as a result, little information on their distribution in the Pacific Ocean has been obtained.

The distribution of masu salmon in the Sea of Japan will be discussed in detail in the following section. Because of this, their offshore distribution will be discussed only briefly in this section, with some description of other aspects of their marine life.

2.6.1 Distribution and migration of masu salmon in the Sea of Japan. Young masu salmon remain in coastal waters during the summer following their entry into the sea and are caught incidentally by coastal trap-nets. Meanwhile, they have grown to a size of 20 cm or more in body length. Then, with the exception of a few sporadic catches in coastal waters, they disappear from the area. Along the coast of Hokkaido, masu salmon of about 30 cm in total length are often caught during the period from October to December (Ono, 1933). On the coasts of the isolated islands of Rishiri, Teuri and Yangeshiri, off the northern part of Hokkaido, the handline fisheries for masu salmon start around early or mid-November (Konda *et al.*, 1952). On November 17, one masu salmon was caught in the area off Cape Lopatin on the west coast of southern Sakhalin by an expedition fishing experimentally for herring. This specimen was 32.5 cm in body length and weighed 385 grams. (Dvinin, 1956.) In mid and late January, the handline fishery for masu salmon starts on the southern coast of Hokkaido

along Tsugaru Strait and the Shakotan Peninsula (Konda *et al.*, 1952; Hirano, 1940). On the isolated islands off northern Hokkaido, as well as along the southern coast of Hokkaido, the catch of masu salmon drops off sharply in February or March. At Kamoenai along the west coast of the Shakotan Peninsula in southern Hokkaido, the handline fishery for masu salmon started in late January in 1940. The masu salmon caught by this fishery on March 1 of that same year were examined and it was found that their fork lengths ranged from 32 to 45 cm and their weights ranged from 350 to 1,250 grams (Hirano, 1940). In summary, it appears from the patterns of the fisheries along the Hokkaido coasts that, during the winter, schools of masu salmon migrate southward in the Sea of Japan at some distance offshore from the coast of Hokkaido. Apparently most of them reach the waters south of Tsugaru Strait by February or March. The pattern of the offshore gillnet fishery in the Sea of Japan supports this assumption.

The drift gillnet fishery in the Sea of Japan starts in early March and at first is centered in the locality between the latitudes of 38°N and 40°N. Some fishing operations by research vessels have been carried out as early as late February. The number of fish caught per unit of gear is highest at the beginning of the season, when it exceeds 0.5 fish per tan⁶. The fishing ground extends westward between the latitudes of 38°N and 40°N and as far west as 135°E. The area of concentration of masu salmon extends as far west as the fishing ground does. The fishery operates in this same locality until early April, but the overall relative abundance of masu salmon decreases sharply after early March. During the earlier part of the fishing season, the catch of masu salmon contains specimens ranging in size from 35 to 45 cm in fork length. The average fork length at this time is approximately 40 cm, but as the season progresses the size of the fish increases. After mid-April, the fishery is centered noticeably farther northward than earlier in the season. The southern boundary of this fishing ground is located approximately along the latitude of 38°N until the end of April, but by the end of May this boundary has shifted to approximately 40°N. In comparison, the northern boundary of the fishing ground extends as far north as the southwest coast of Hokkaido in late April and as far north as the Rishiri and Rebun Islands in mid-May. The area covered by the fishery increases remarkably after mid-April, while the average density of masu salmon decreases

⁶ *Tan* is a Japanese term used to describe a quantity of net. In the case of the salmon gillnet fishery, a tan measures approximately 50 m along the float line and 6 m deep in the water.

considerably. In June, there are very few masu salmon observed in the area.

The fish grow larger as the season progresses and by April and May the mean fork length is 45 cm or more, which is approximately the size of mature fish. Very few masu salmon more than 50 cm in fork length are caught by drift gillnets. The growth of masu salmon taken by gillnet in the Sea of Japan can be summarized as follows—the mean fork length in late February is about 38 cm and increases thereafter by about 1 cm every ten days. Information on the size of masu salmon in the ocean is summarized and shown in Figure 1.

It appears that the longline fishery in coastal waters of Ishikawa Prefecture from late February to mid-April (Tabata *et al.*, 1959) and the trap-net fishery in the same area during March and April are taking masu salmon from the southernmost edge of their distribution at a time when their overall distribution extends farthest south. The handline fishery along the Japan Sea coast of Hokkaido takes place during March to April or May in the southern part and from late April or May to not later than the end of June in the northern part (Konda *et al.*, 1952). These timings agree well with the timing of the northward shift of

offshore gillnet fishing grounds along the Japan Sea coast of Hokkaido.

Along the coast of North Korea, masu salmon are fished by trap-nets from February to June, inclusive. For comparison, the following information relating to movements of pink salmon along the coast of North Korea is presented. Small young pink salmon ranging between 20 and 30 cm in total length are caught during the period from late November to late December, while from April to June larger pink salmon ranging from 40 to 50 cm in total length are taken as they migrate northward along the coast (Yoshida, 1942). The movement of masu salmon may be similar to that of pink salmon. However, no evidence is available so far as to whether or not masu salmon stocks from off North Korea and those from off the west coast of Honshu are continuously distributed across the Sea of Japan.

In the gillnet fishing grounds, masu salmon are caught in waters with surface temperatures between 8° and 12°C. The largest catches are obtained when the surface temperature is approximately 10°C. This 10°C isotherm is located along the Polar Front in the Sea of Japan. Therefore, it appears that the area

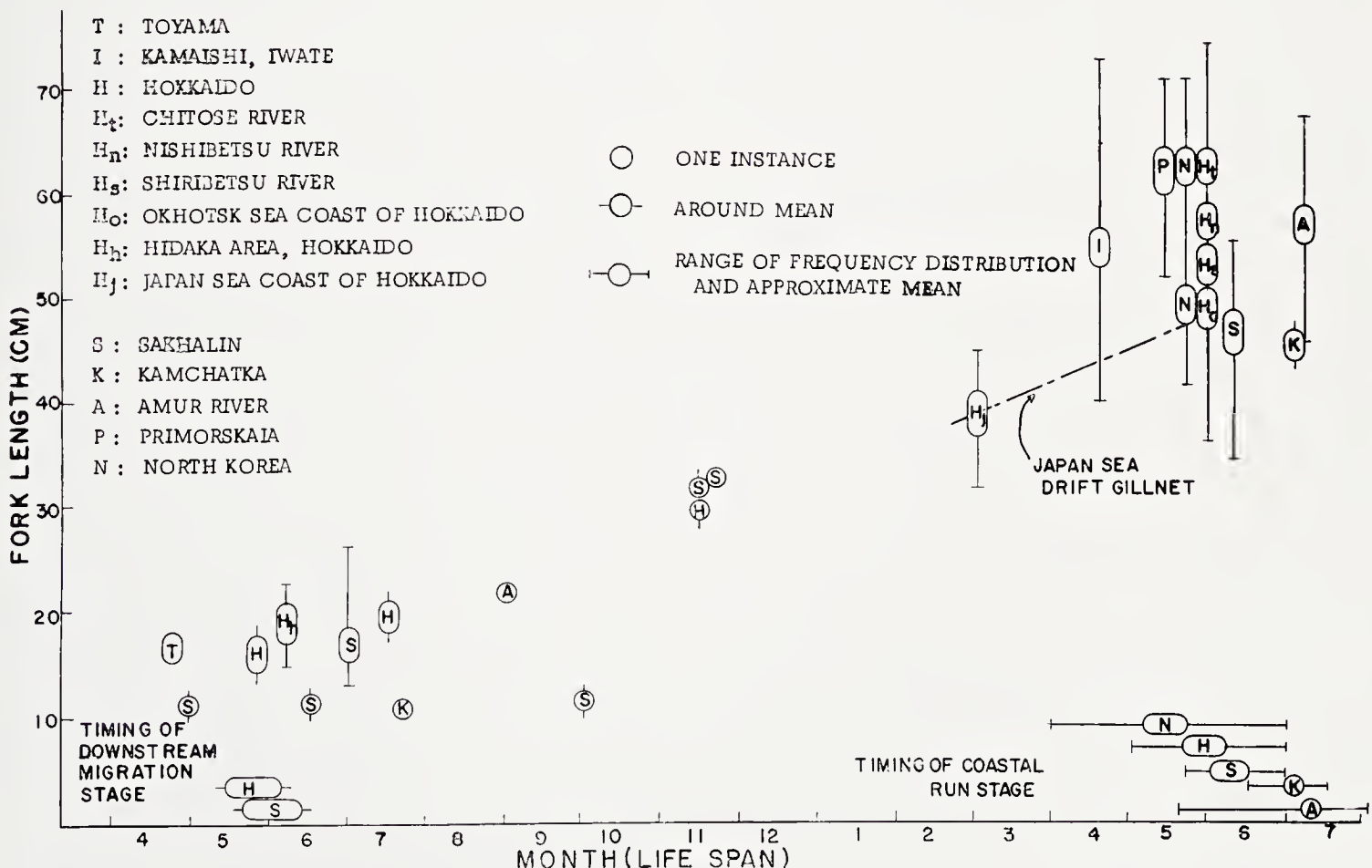


FIGURE 1. The range and approximate mean of fork lengths of masu salmon at various stages of life.

of concentration of masu salmon shifts as the Polar Front zone moves. In the Sea of Japan, the January, February and March surface temperatures fall below 0°C in waters north of Soya Strait and in waters along the Primorskaia coast. Thus, it is assumed that masu salmon are forced to move south or east of these waters during the winter (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956; Japan Sea Reg. Fish. Res. Lab., unpub.).

Very few tagging experiments have been carried out on masu salmon in the Sea of Japan. Of seven masu salmon released at 38°48'N, 138°23'E, on April 21, 1959, one was recaptured in a small trap-net near Sawabe, Iwasaki Village, Nishitsugaru-gun, Aomori Prefecture, on May 1. This fish had moved 126 nautical miles northeast in eleven days, averaging 11.5 miles per day. (Japan Sea Reg. Fish. Res. Lab., unpub.)

By combining all the above information, the following pattern of migration of masu salmon in the Sea of Japan might be assumed. The young masu salmon which enter the sea from streams along Hokkaido, Sakhalin and Primorskaia and from the Amur River stay in coastal waters and estuaries until July and then move gradually toward offshore areas. They move southward in the Sea of Japan during the autumn when the surface water temperatures are gradually falling. They reach the areas off the west coasts of Sakhalin and northern Hokkaido in November or December and in January or February they pass through the offshore waters off the west coast of southern Hokkaido. From late February until early April, they occur as far south as approximately 38°N to 40°N, the southern extent of their distribution. In late April, when the Polar Front starts shifting northward, masu salmon also start northward migrations. They first migrate to the area off the southern Hokkaido coast and by the end of May they have reached the area off northern Hokkaido or the coast of Primorskaia. Further northward migration is continued in June. It is also assumed that another stock migrates southward in the fall and northward during April, May and June along the North Korean coast in the western part of the Sea of Japan.

The times of the spawning migrations along the coasts of the Sea of Japan are approximately as follows: in Ishikawa Prefecture (approximately 37°N) they occur between February and June, inclusive, whereas those which occur on the coasts of Hokkaido, Sakhalin and West Kamchatka do not take place until June and July. By considering these facts, it can be surmised that masu salmon along the coast of Honshu and Hokkaido stay in coastal waters and estuaries for

about one month before starting their upstream migration.

The abundance of masu salmon as indicated by the catch per unit of drift gillnet decreases very rapidly from a maximum in early March to a catch of almost nil in June. This is probably partly because some of the stocks leave the area of abundance for waters along Primorskaia instead of migrating northward with the bulk of the stocks and partly because the stocks bound for the rivers of Honshu and Hokkaido leave the area of concentration and move into coastal waters. These stocks are thus no longer subjected to the drift gillnet fishery. Kawakami (1937b) suggested a similar theory for the chum salmon fisheries along the coast of Hokkaido. Further analysis of the other types of fisheries in coastal waters will help clarify these points.

2.6.2 Feeding habits. Examination of stomach contents of masu salmon caught in offshore waters of the Sea of Japan showed that masu salmon are completely carnivorous and that they depend on other fish to form a significant proportion of their food. From research carried out by the Japan Sea Regional Fisheries Research Laboratory, it has been shown that the composition of the stomach contents varies according to the time of the northward migration. In March and April, large crustaceans are dominant in the stomach contents of masu salmon. Some fish are also present in the stomachs. In May, certain species of fish and squid are the dominant items in the stomach contents. The size of these food items is considerably larger than that of the food taken earlier in the year. Similar results are reported by the Hokkaido Prefectural Fisheries Experimental Station and Hokkaido Regional Fisheries Research Laboratory (1956). The series of samples used for this report was collected in areas adjacent to Okujiri Island. In the sample collected on April 21, 1955, Amphipoda and Euphausiacea were the most abundant food items, whereas in the sample collected between April 28 and May 3, fish were the most abundant. In the sample collected on May 9, squid and fish were the most abundant food items. The species of fish utilized by masu salmon included *Maurolicus japonicus* and *Pleurogrammus azonus*, two very abundant species in this area. According to Dvinin (1956), young masu salmon along the west coast of Sakhalin feed on crustaceans and small young fish for a period immediately after their entry into the sea from the rivers. In comparison, he reports that adults which returned to the coast were found to have fed mainly on certain fish, including *Pleurogrammus*, herring and others.

By combining all this information, it may be concluded that young masu salmon usually feed on crus-

taceans and their diet changes as they grow older, until fish become the most important food item. This transition seems to take place around April after they have spent one winter in the ocean. The length of food organisms found in masu salmon stomachs did not exceed one-half that of the predator. One thing that should be noted concerning the transition in feeding habits of masu salmon is that in March animals of a size suitable for masu salmon food are low in abundance in the area where masu salmon are most abundant. Another fact is that many different species were found in the stomach contents of masu salmon. These included *Pleurogrammus azonus*, *Maurolicus japonicus*, *Arctoscopus japonicus*, herring (*Clupea pallasii*), saury (*Cololabis saira*), Pacific mackerel (*Scomber japonicus*), sardine (*Sardinops melanosticta*) and anchovy (*Engraulis japonica*). The presence or absence of these species in the stomach contents from a particular area is in some cases a reflection of their geographical distribution. This variety of food organisms indicates that masu salmon feed on whatever species of small fish are encountered and that when small fish are not available they feed on large planktonic crustaceans. (Japan Sea Reg. Fish. Res. Lab., unpub.)

2.6.3 Maturation. Unlike in other species of salmon, the gonads in masu salmon do not start rapid growth until after the fish enter freshwater streams. Masu salmon in the ocean have rather immature gonads. However, some gonad development is observed during the offshore driftnet fishing season, which lasts from March to May, inclusive.

The proportion of gonad weight to total body weight is given by month in Table 17. These data have

been collected by the Japan Sea Regional Fisheries Research Laboratory since 1957. If we review these data in further detail, according to the dates when samples were collected, it can be seen that rapid gonad development starts in April. The mean diameter of ova taken from different specimens collected on May 10 and 11 ranged from 2.5 to 4.0 mm. The maximum size of an individual ovum was 4.5 mm. As indicated in Table 17, similar results were obtained for samples collected in the ocean near Okujiri Island. (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956.) Some development of gonads was observed during the period between April 29 and May 9. It was noted that fish in samples taken near Okujiri Island were more mature than those collected from the Shinsha River (Table 17). This was an indication that the stocks near Okujiri Island would go into the rivers very soon. The diameters of ova collected from specimens sampled around Okujiri Island were 3.3 mm at a maximum and 2.7 mm on the average.

2.6.4 Sex ratio. The dominance of females is apparent in the stocks of masu salmon distributed in the ocean, just as it is in the downstream and spawning migrations in fresh and coastal waters. The sex ratios of fish in samples collected in the Sea of Japan by the Japan Sea Regional Fisheries Research Laboratory in 1957, 1959, 1960 and 1961 are given by month in Table 18. As is the case in pink salmon, there is a tendency for slightly more males to be present in the earlier part of the fishing season. However, there is no doubt that, as a whole, females are the predominant sex. The percentages of females in these samples vary from 60% to 70% after February. This range of percentage also applies to the spawning migrations

TABLE 17. Monthly development of maturity [(gonad weight/body weight)×100] of masu salmon during their marine life, in percentages.

Area	Sex	March	April	May	June	July	Matured (Sept.)
The Sea of Japan	Male	0.16	0.18	0.44			
	Female	1.09	1.72	3.01			
Okujiri Island	Male		0.3	1.2			
	Female		2.0	2.5			
Shinsha River (from Table 10)	Male				0.5	5.8	6.5
	Female				1.7	7.4	26.8

TABLE 18. Sex ratio of masu salmon caught in the Sea of Japan.

Sex	February		March		April		May		June		Total	
	No. of fish	Percent	No. of fish	Percent	No. of fish	Percent	No. of fish	Percent	No. of fish	Percent	No. of fish	Percent
Male	21	80.8	92	37.9	120	29.3	49	29.5	4	36.4	286	33.5
Female	5	19.2	151	62.1	289	70.7	117	70.5	7	63.7	569	66.5

in most coastal waters and streams. It is especially applicable in Hokkaido. In addition, a similar proportion of the downstream migrants in Hokkaido are also females. (See sections 2.1.6, 2.5.2.)

2.6.5 *Masu salmon in the North Pacific.* Very little information has been obtained on the life history and migration of masu salmon in the Pacific Ocean. Interviews held in the area around Ozuchi and Kamaishi revealed that pink salmon migrate southward as far as Kinkazan, Miyagi Prefecture, in March and return northward in April, May and June. The migration patterns of pink and masu salmon in the Sea of Japan were much the same, so it is assumed that the migration pattern of masu salmon in the Pacific

Ocean is somewhat similar to that of pink salmon.

The distributions of surface water temperatures in the area off the coast of Sanriku are shown by month in Figure 2 for the period from January to June in 1960 and 1961, respectively. The values are those for the middle of each month. The data were taken from the monthly reports of the pattern of fishing and ocean conditions published by the Tokai Regional Fisheries Research Laboratory. Because of its relation to the masu salmon fishery, special attention is given to the 10°C isotherm. It occurred in the vicinity of Cape Todo in January, when the water temperature was still rather warm. In February, the 10°C isotherm shifted southward to an area off Kinkazan or

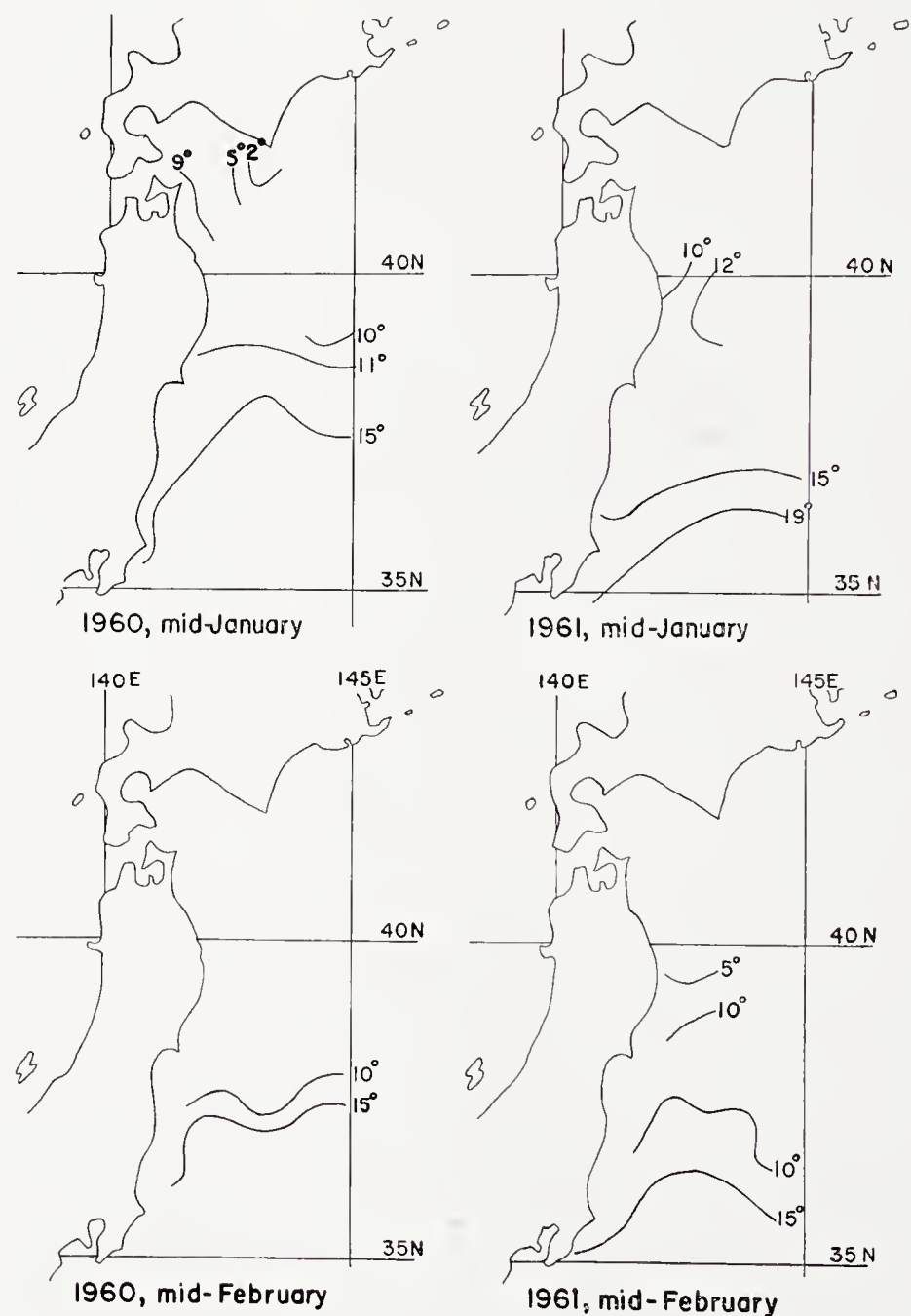
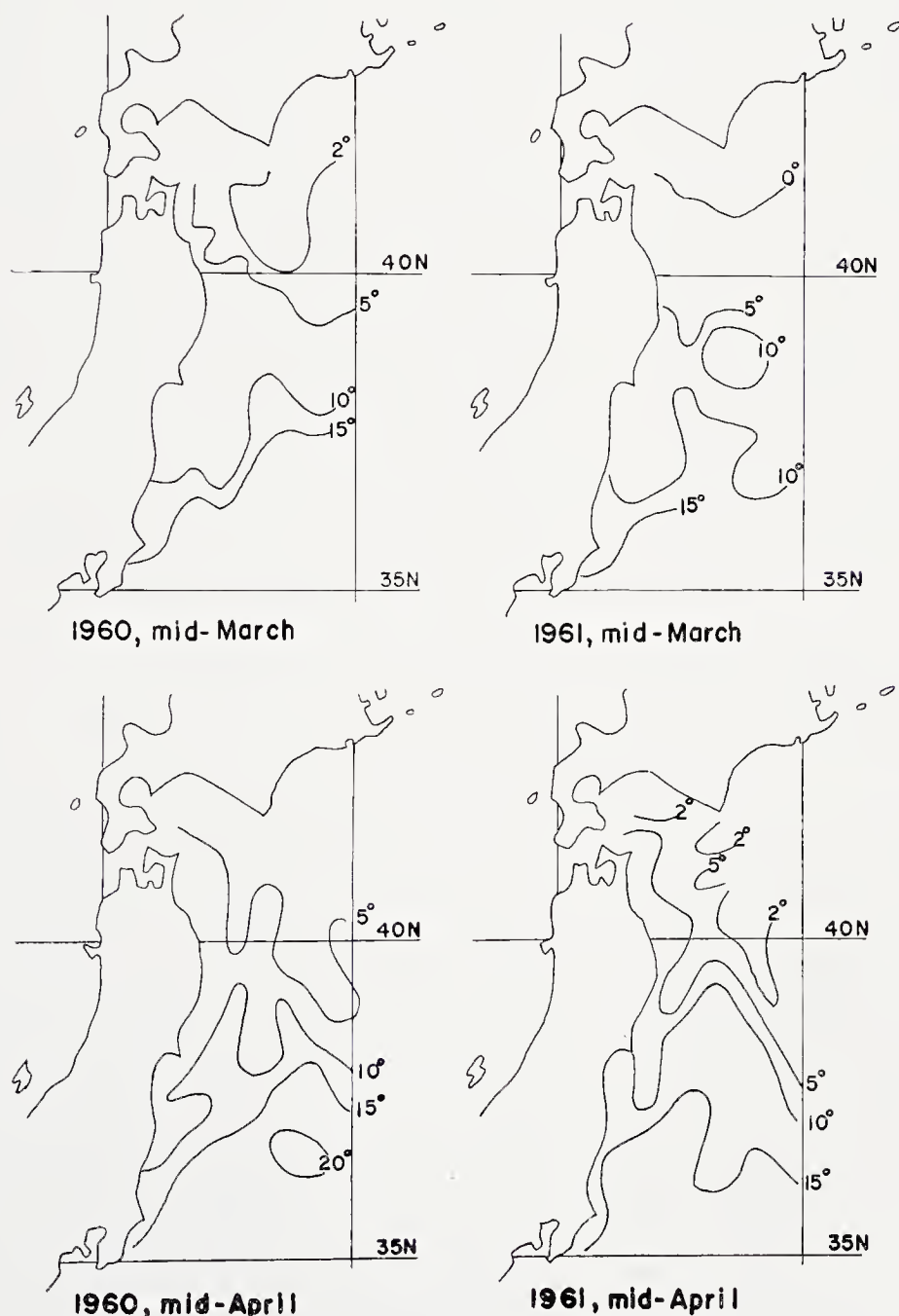


FIGURE 2. Distribution of surface water temperatures in areas offshore from

Shioyazaki. The surface water temperature off the coast of Sanriku was as low as 5°C . Oceanic conditions during March were somewhat similar to those during February; however, there was some extension of the cold water mass originating in the Hokkaido area. The temperature of this water mass was almost 0°C and in March it extended as far south as the area off Hachinohe and Cape Todo. In April, the Kuroshio current extended northward, gaining strength rapidly and, as a result, there was an increase in the water temperature of coastal waters. Because of this, the 10°C isotherm was pushed northward as far as the area off Kinkazan. The area in which the surface water temperature was below 5°C was forced far to the north. In May, the 10°C isotherm moved as far

north as the area off Hachinohe and Cape Todo and left cooler water masses along the coast. The area in which the surface water temperature was below 5°C shifted northward to the area off Hokkaido and was further reduced in size. In June, the surface temperature even in coastal waters was almost 15°C . The 10°C isotherm moved farther north to the area off Hachinohe.

The general distribution pattern of the various species of salmon in the area off Sanriku on the Pacific coast of northern Honshu seems to correspond with the seasonal fluctuations in water temperature mentioned above. During February and March, the season when the water temperatures prevailing along



northern Honshu in the Pacific Ocean, January to June, 1960 and 1961.

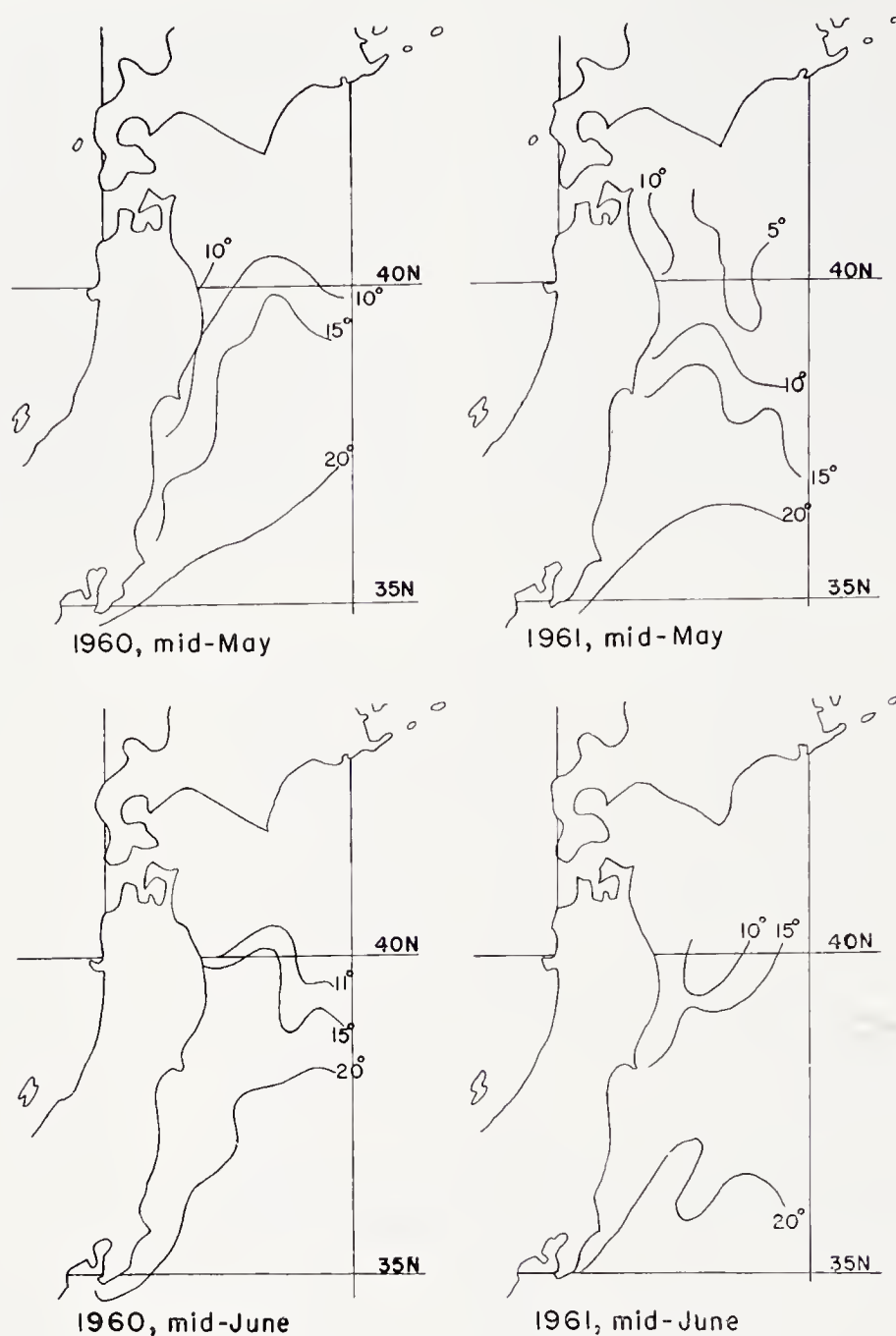


FIGURE 2. Continued.

the offshore areas of northern Japan are the coldest, salmon are distributed in the waters off Kinkazan and farther south as far as off Fukushima Prefecture. However, when the surface water becomes warmer in April and May, they begin migrating northward in offshore areas and in June reach the area off Hokkaido. In the coastal waters along Sanriku, another less important catch peak of masu salmon occurs in September. The spawning run to the Ozuchi River, which is in this district, was reported to be in August and September. In this period, the surface temperature of coastal waters in this area exceeded 20°C by a considerable amount. However, the distribution of water temperatures at 100 meters depth indicates that at this depth there is a water mass distributed off Sanriku

with a temperature of approximately 10°C.

Fairly large amounts of masu salmon are fished along with pink salmon by coastal trap-nets on the Pacific coast of northern Japan. This fishery is mostly confined to Iwate Prefecture and to the months of April and May. On the contrary, the offshore gill-net fisheries, as well as the longline fisheries by land-based fishing vessels, cover the offshore area southeast of Hokkaido during May and June, but catch very few masu salmon. From late May to late June, 1949, there was some experimental fishing with gillnets in waters less than 15 nautical miles from the Pacific coast of Hokkaido. In these catches, masu salmon contributed only 5.92% of the total catch. In addi-

tion, in similar catches made in the same area during mid and late June, 1950, the proportion of masu salmon was much smaller. At this time, only one masu salmon was counted in the total catch of about 4,000 fish. (Sato *et al.*, 1953a, 1953b.) These data seem to indicate that masu salmon in the Pacific Ocean migrate southward and northward in waters close to the shore of Japan. They also indicate that the abundance of masu salmon is relatively small compared with that of other species of salmon in the Pacific or with that of masu salmon in the Sea of Japan.

Ten recoveries were reported from one lot of fish tagged and released in the coastal waters of Hidaka, Hokkaido, between June 14 and 24, 1930 (Hirano, 1953). Of these ten recoveries, eight were reported from locations to the northwest of the points of release. These fish had moved between 13 and 48 km in from two to 16 days. These recoveries suggested a general northwesterly movement of masu salmon along the coast of Hidaka district, Hokkaido.

By reviewing catch records of masu salmon taken in coastal trap-nets along the Pacific coast of Hokkaido, it was found that almost no catches of masu salmon were recorded from near the Kushiro area. The records also showed that considerably more masu salmon were caught along the coasts of Hidaka, Iburi and Oshima. Judging from this, it appears that after the masu salmon have passed northward along the Sanriku coast of Honshu they move along the coast of Hokkaido west of Hidaka towards the Uchiura Bay (Funka Bay) area. The results of the tagging experiments described above do not contradict this assumption. The biggest catches of masu salmon along the Pacific coast of Hokkaido are usually made in the Oshima district along the shore facing Tsugaru Strait. This suggests that there is some possibility that masu salmon which move northwards in the Sea of Japan enter the Pacific Ocean through Tsugaru Strait. Also, the possibility cannot be rejected that some proportion of masu salmon migrating northwards along the Sanriku coast in the Pacific may be bound for Siberian streams, as is the case with pink salmon.

Masu salmon caught in the Pacific are a little larger than those caught by gillnet fisheries in the Sea of Japan. The specimens collected by gillnets along the Pacific coast of Hokkaido in 1949 ranged from 49 to 63 cm in total length and from 1.4 to 2.7 kg in body weight. The average total length and body weight were 54.6 cm and 2.0 kg, respectively. (Sato *et al.*, 1953a.) The catches of masu salmon landed in April 1962 at Kamaishi by the local longline fishery were examined by the author and it was found that

the fork length ranged from 41 to 67 cm, with an average of 53.4 cm. The body weight ranged from 1.0 to 5.0 kg and averaged 2.25 kg. It should be noted that the difference between the sizes of fish in the Sea of Japan and the Pacific Ocean might be due partly to differences in the selectivity of the gear.

2.7 FRESHWATER-TYPE MASU SALMON (YAMAME)

The freshwater-type masu salmon are not a significant commercial fish, although they are highly prized as game fish. However, the existence of freshwater-type masu salmon does provide many interesting problems in ecology.

The freshwater-type masu salmon, which in this section will be referred to as yamame, are distributed over almost all of Japan. They even occur in waters where no anadromous masu salmon are found. Semko (1956) found two specimens of yamame in the upstream part of the Bolshaia River.

Masu salmon which do not start downstream migration in the spring after spending one winter in fresh water turn a gold color during the following April and May. They become a darker color during the following summer and autumn. After these color changes, the males attain maturity and at least some of them appear to mate with the females which have migrated up from the ocean to the spawning grounds. Female yamame can also mature in the third year after hatching or in some cases they may mature even later. (Ono, 1933.) Some males attain maturity within one year after hatching (see section 2.4.3).

The proportion of the fry which will become yamame seems to be variable according to the area and the particular circumstances. Fujita (1933) reported that 37 out of 103 (36.9%) of the masu salmon fry used in his feeding experiments became yamame. The fry used by Fujita were obtained from spawners which had migrated to the Kurobe River. Saguri (1936) reported that 217 out of 373 (58.1%) of the masu salmon fry from Hokkaido streams used in feeding experiments became yamame, whereas only 33 out of 98 (38.8%) of the fry from Kurobe River became yamame. In Hokkaido, all streams (except those which are geographically land-locked) that have yamame also have runs of masu salmon. There are some instances where the construction of a dam caused the yamame to disappear from the upstream parts of a river by preventing the migration of the spawning run of masu salmon (Fujita, 1933). On the other hand, yamame occur in the streams of some areas in southern Japan where no anadromous-type masu salmon or spawning runs of masu salmon occur.

This might be because the temperature of the downstream parts of the stream or that of the coastal water near the stream might be too high to have either downstream migrations or runs of masu salmon. Along the Taiko River in Taiwan, yamame are found only at altitudes of 2,000 m or more above sea level (Oshima, 1957).

Male masu salmon fry have a stronger tendency to become yamame. The data collected by Ono (1930) clearly indicated this tendency (see section 2.5.2). In a series of feeding experiments carried out at a hatchery in Toyama Prefecture by Saguri (1936), 436 out of 578 (75.4%) of the fish which became yamame were males. However, the sex ratio of yamame found in streams lacking the anadromous-type masu salmon is almost 1 to 1 (Ono, 1933).

Yamame show very poor growth compared with anadromous-type masu salmon, which spend a part of their lives in the sea. By the end of their second year after hatching, yamame are only about 20 cm in length and after three years they are only about 25 cm. There is also a large variation according to geographical area as well as to the individual. Very few three-year-old yamame are found. The fecundity of female yamame is also low, averaging only 200 to 300 eggs. The average diameter of the mature ova is approximately 0.5 cm. (Ono, 1933.)

Under favorable conditions, yamame grow as large as anadromous-type masu salmon at the time of spawning. The conditions necessary are that they live in a cool lake and that there is abundant food. Good examples are the yamame transplanted to Lake Toya and Lake Biwa. However, in these cases, the age at maturity varies from the third to the sixth year of life. (Ono, 1933; Ono and Ando, 1932.)

It is generally accepted that, under natural conditions, all fish belonging to the genus *Oncorhynchus* die after spawning. However, the scales of some yamame have what is considered to be a spawning check (Ono, 1933). In some feeding experiments, yamame have spawned successfully two or more times.

3. OFFSHORE DISTRIBUTION OF MASU SALMON

In the eastern half of the Sea of Japan, extensive gillnet fisheries are conducted from March to May or June for pink and masu salmon. Some statistics on the catch of masu salmon are collected from commercial fishing vessels. In addition, some biological studies of masu salmon are made by research vessels

from the prefectural fisheries experimental stations. This information is not adequate, and is very limited compared to that collected for other species of salmon, but it is nevertheless sufficient to obtain some new knowledge of masu salmon in offshore areas of the Sea of Japan. In the following sections, the distribution of masu salmon in the offshore waters of the Sea of Japan is reviewed. This analysis of the distribution is based on the catch statistics obtained from the commercial fisheries and on the size composition (fork length) of the fish collected by research vessels.

3.1 GILLNET MESH SELECTIVITY

Most of the salmon fisheries in the Sea of Japan are conducted with drift gillnets. In addition, most of the biological data collected by commercial fishing vessels and research vessels are also based on gillnet catches. Therefore, the efficiency and selectivity of gillnets are basic problems to be considered. Fortunately, some of the catches made by the prefectural research vessels were recorded according to the different mesh sizes of drift gillnets (Japan Sea Reg. Fish. Res. Lab., unpub.). These data can be used for the analysis of the catch per unit of effort for different mesh sizes. The gillnet mesh selectivity for masu salmon is discussed with reference to the mesh selectivity curves constructed by Ishida (1962) for pink salmon and some of the other species of salmon.

3.1.1 Variation in catch per tau by different mesh sizes. Since the catch of masu salmon by drift gillnets is comparatively small, and since most masu salmon are caught in the earlier part of the season, catch statistics on masu salmon are available only for the earlier part of the season. In some catch statistics, catches of masu salmon were combined with those of pink salmon. In cases where masu salmon and pink salmon catches were combined, the predominant species was assigned the catch of both species.

For several reasons, it was a little difficult to compare the fishing efficiency of nets of different mesh sizes by combining the results of several operations. First, the units of fishing effort (in number of tans of gillnet) used in one operation were not all composed of the same proportion of different mesh sizes. In addition, the catch per unit of effort is primarily determined by the relative abundance of fish at the time and the place of operation. Therefore, the following procedures were applied. If it is assumed that at the t^{th} operation, C_{mt} fish are caught using X_{mt} tans of gillnet of mesh size m , and if the random variations are ignored, then

$$C_{mt} = q_m \cdot X_{mt} \cdot D_t,$$

where q_m is the relative fishing efficiency of a gillnet of m mesh size and D_t represents the density of fish at this particular operation. The catch per unit of effort is then

$$C_{mt}/X_{mt} = q_m \cdot D_t.$$

The mean value of the logarithms of this equation for n operations can be calculated as follows:

$$\frac{1}{n} \sum_{t=1}^n \log (C_{mt}/X_{mt}) = \log q_m + \frac{1}{n} \sum_{t=1}^n \log D_t.$$

On the right-hand side of the equation only the logarithm of the variable D_t (fish density at t^{th} operation) is averaged.

$$\log D_t - \frac{1}{n} \sum_{t=1}^n \log D_t$$

represents the density of fish at the t^{th} operation in relation to the average density during n operations. The standardized catch per tan in logarithms will be obtained by subtracting this correction factor from the logarithm of catch per tan of each fishing operation. When correction factors are determined for more than one mesh size, then the arithmetic mean

of these factors can be used. If a particular mesh size is not used in all of the n operations, then it is not appropriate to take the average of relative abundance indices for nets of that particular mesh size. In such cases, the mean of the correction factors should be calculated using only the data for the mesh sizes used during all n operations. Then the density indices for each operation will be represented by this mean value. The catch per tan statistics recorded by nets of the mesh sizes in question which were not used in all the operations can be standardized using these density indices. The average catch per tan value for nets of these particular mesh sizes can then be obtained by averaging only the values obtained for the operations which did use this mesh size. The mesh sizes which were used in all the operations and subsequently were used as the standards include 97, 100 and 103 mm stretched mesh (distance between opposite knots) in 1959 and 91 and 97 mm stretched mesh in 1960. Some results obtained by using the above-mentioned equations are shown by ten-day periods in Table 19. Also, summarized results are shown in Figure 3. The values for pink salmon are also shown for comparison.

Although the fishing efficiency curve for masu salmon is apparently considerably different from that for pink salmon, the inadequacy of the data on masu

TABLE 19. Standardized catches (in number of fish) per tan of drift gillnets in the Sea of Japan. (The figures given in the table are the logarithms of the number of masu salmon caught per tan, multiplied by 10. Also see text, p. 99.)

Species	Year	Ten-day period	Mesh size (mm)							Proportions in catches
			85	91	94	97	100	103	106	
Masu salmon	1959	late Feb.		0.623		0.793	0.820	0.845		120 : 0
Pink salmon	1959	early March		1.603		1.463	1.424	1.244		0 : 414
"	"	mid-March		1.436		1.443	1.383	1.304		0 : 402
"	"	late March		1.484		1.502	1.406	1.223		0 : 1214
"	"	early April		1.388	1.754	1.491	1.295	1.346		0 : 4150
"	"	mid-April		1.276	1.568	1.459	1.336	1.337	-0.374	0 : 3308
"	"	late April		1.511	1.534	1.545	1.298	1.289		56 : 3505
		Average		1.420	1.619	1.491	1.343	1.304	1.037	
Masu salmon	1960	late Feb.		0.926		0.959	0.673			
"	"	early March		1.061	0.832	0.885	0.746	0.425		169 : 13
"	"	mid-March				0.854	0.774	-0.243	0.016	977 : 143
"	"	late March	0.482	0.593		0.684	0.948	0.283	0.217	396 : 2
		Average	0.482	0.847	0.832	0.834	0.798	0.266	0.274	80 : 22
Pink salmon	1960	late Feb.		1.586	1.489	1.205	1.549	1.641		2 : 337
"	"	mid-March		1.531	1.756	1.260	1.376	0.869	1.158	400 : 1667
"	"	late March		1.563	1.619	1.229	0.716	0.514		58 : 718
"	"	early April	1.468	1.451	1.411	1.341	1.393	1.234	1.409	205 : 7010
		Average	1.468	1.506	1.537	1.286	1.285	1.098	1.284	1.144
Masu salmon	1961	early March		1.090			0.977		0.354	68 : 5

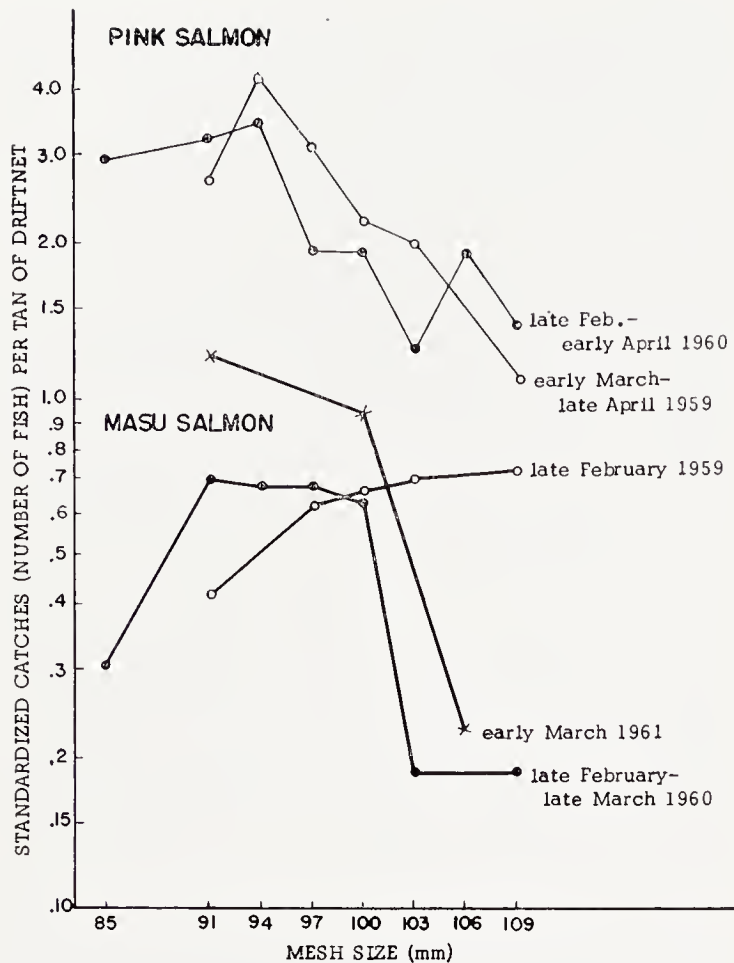


FIGURE 3. Fishing efficiency by mesh size for salmon drift gillnets used in the Japan Sea salmon fisheries.

salmon does not permit a test of the significance of this difference. Assuming that this curve adequately represents the fishing efficiency of the gillnets, then the mesh sizes between 91 and 100 mm stretched mesh could be expected to be equally efficient in catching masu salmon during February and March, the earlier part of the season. Not many data are available for the middle and later periods of the season. However, judging from the fact that the sizes of the fish in the catches became larger, it is probable that the most efficient mesh size would be correspondingly larger as well. On the other hand, there is no indication that the selectivity curve for pink salmon changes markedly between March and April.

In summary, the gear efficiency does not seem to be variable for the mesh sizes within the range between 91 and 100 mm stretched mesh. However, some of the meshes used do not fall within this range and it is possible that their fishing efficiency may be as low as one-half or even one-quarter that of the most efficient mesh sizes.

No authoritative information is available as to the mesh sizes used in the commercial gillnet fishery.

These sizes are believed, however, to be between 3.0 and 3.3 *sun*⁷ (91 to 100 mm stretched mesh). In 1955, the cumulative total amount of gillnet used by the government-sponsored experimental fishing vessels (43 vessels) which operated near Okujiri Island was 30,000 tans. Of this total, 29,000 tans (95.0%) were 3.3 *sun* or 100 mm mesh nets and all the rest were between 2.9 *sun* (88 mm) and 3.9 *sun* (118 mm) (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956). As a result of these facts, it can reasonably be considered that almost all the gillnets carried by the commercial fishing vessels have a fairly consistent fishing efficiency.

3.1.2 Gillnet mesh selectivity curve. We can obtain the mesh selectivity curve for gillnets of a certain mesh size on stocks of various sized salmon from the size composition of catches made by gillnets of various mesh sizes (Ishida, 1962). Unfortunately, such size composition data are not available for masu salmon. Therefore, based on the mesh selectivity curve obtained by Ishida for pink salmon, some inferences were made for selectivity of masu salmon as well.

The mesh selectivity curves of gillnets of several mesh sizes for pink salmon are shown in Figure 4. Since the proportion of the body depth to the body length increases markedly as masu salmon increase in size (see section 4.4), the slope of this selectivity curve for the larger fish is probably steeper for masu salmon than for pink salmon. Comparison of the selectivity curves estimated by Ishida (1961) for sockeye salmon and pink salmon shows that for the 121 mm mesh the shapes of the curves are quite similar for fish less than 55 cm in fork length. This comparison supports the assumption that selectivity curves

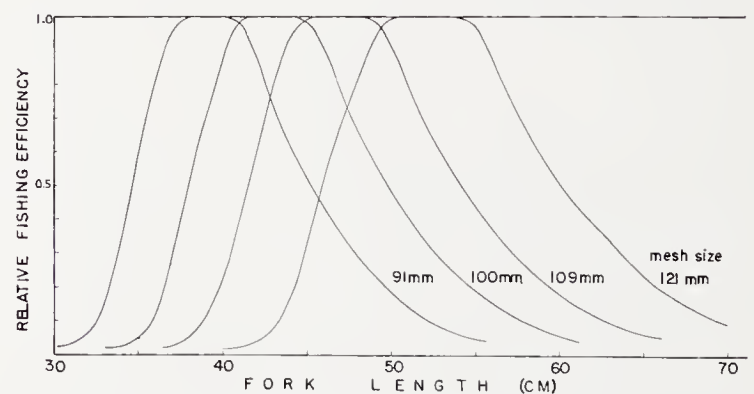


FIGURE 4. Mesh selectivity curves for drift gillnets in pink salmon fisheries. (The 121 mm curve (from Ishida, 1962) was used as a basis for estimating the other curves.)

⁷ Japanese unit of length. One *sun* is approximately equal to one-tenth of one foot.

are similar for different species of salmon and helps to justify substitution of the selectivity curve for pink salmon in place of the one lacking for masu salmon as a means of obtaining some general information.

The size composition of masu salmon for the period between late February and late March in 1960 (Figure 15) shows that most of the fish were from 35 to 45 cm in fork length. Also, as is shown in Figure 3, it is known that gillnets with a mesh size of 91 to 100 mm catch masu salmon very efficiently during this period. In the case of pink salmon, the peak of the selectivity curve for this mesh size range is located at around 35 to 45 cm. These facts also support our assumption that the selectivity curve for masu salmon is basically not much different from that for pink salmon.

The information on fork length used in these analyses (see section 3.5) was obtained by experimental fishing vessels operated by the prefectural fisheries stations. Some of these data gave records of the fishing effort including information on the number of tans of different mesh sizes used. For example, in 1959, out of 12,000 tans of net, 27.1% were 91 mm stretched mesh, 20.5% were 97 mm, 23.1% were 100 mm, and 14.6% were 103 mm. The mesh sizes ranged from 85 to 109 mm stretched mesh. Of 26,000 tans of net used during the 1960 fishing season, 32.8% were 91 mm stretched mesh, 21.9% were 97 mm, 20.3% were 100 mm, and 11.9% were 103 mm. The range was from 85 mm to 109 mm stretched mesh. Generally speaking, each research vessel used gillnets of different mesh sizes in the same proportions throughout the season.

From the above data, it may be safely concluded that the gillnets used to obtain samples from which data on the size composition of masu salmon were derived were mostly of mesh sizes from 91 to 103 mm, inclusive. Based on the mesh selectivity curves for pink salmon, the efficiency of the mesh sizes mentioned above is highest for fish of 42 to 43 cm in fork length. The efficiency remains fairly high for fish between 35 and 50 cm, where it is more than one-third or one-half of the maximum value. The slope of the fishing efficiency curves for a combination of several mesh sizes as a whole is much smoother than that of the curves for a single mesh size. In addition, it is generally true that the position of the mode of a length composition is rather stable against the mesh selectivity. Therefore, the position of the mode in a sample would be considered to represent fairly well the true position in a fish stock from which the sample is obtained. However, if the mode of the fish length is small (less than 40 cm), the mode of the size com-

position of the catch could be biased, by 1 or 2 cm, towards a larger size than the mode of the actual size composition of the population in the ocean. Also, the fish larger than 50 cm are not expected to be sampled representatively by gillnets of this mesh size range.

3.2 FLUCTUATION IN ABUNDANCE INDICES BY TEN-DAY PERIODS

In the catch records, the number of fish in the catches of masu salmon plus the cumulative amount, in tans, of gillnet used are given for 20 minute by 20 minute statistical areas and by ten-day periods. As this information was not obtained from all the fishing vessels operating in the Sea of Japan, no information is available as to the total catch of masu salmon and the corresponding total fishing effort by ten-day periods. However, the relative density of fish according to area and time would be given by the catch per tan and then the abundance indices can be calculated. The abundance indices can here be defined as the sum of the average numbers of fish caught per tan in each of the 20 minute by 20 minute statistical areas in which the fisheries operated. Also, the density indices can be obtained by dividing the abundance indices by the number of statistical areas in which the operations were conducted. In these calculations, it was found that during the later part of the season no masu salmon were taken in many statistical areas. These areas were included as having zero catches in one series of calculations, but since they seemed to be at the outside of the distribution area of masu salmon, they were ignored in another series.

The indices for both series of calculations for 1960 and 1961 are shown in Figure 5. The logarithmic values for these indices are shown in Figure 6. The maximum values for the abundance indices are recorded in early March and after this they show a fairly steady decline with some fluctuations. The density indices show a greater decline than the abundance indices. This is because of the tendency for the number of statistical areas to increase as the season progresses. Between 1960 and 1961, these tendencies were consistent, although there was some difference in degree. These tendencies have also been recorded for the years prior to 1960.

The following factors may be responsible for such seasonal fluctuations in abundance indices: (1) change in availability of fish; (2) differences in the efficiency with which gear of certain mesh sizes catches different sizes of fish; and (3) actual variation in the abundance of stocks.

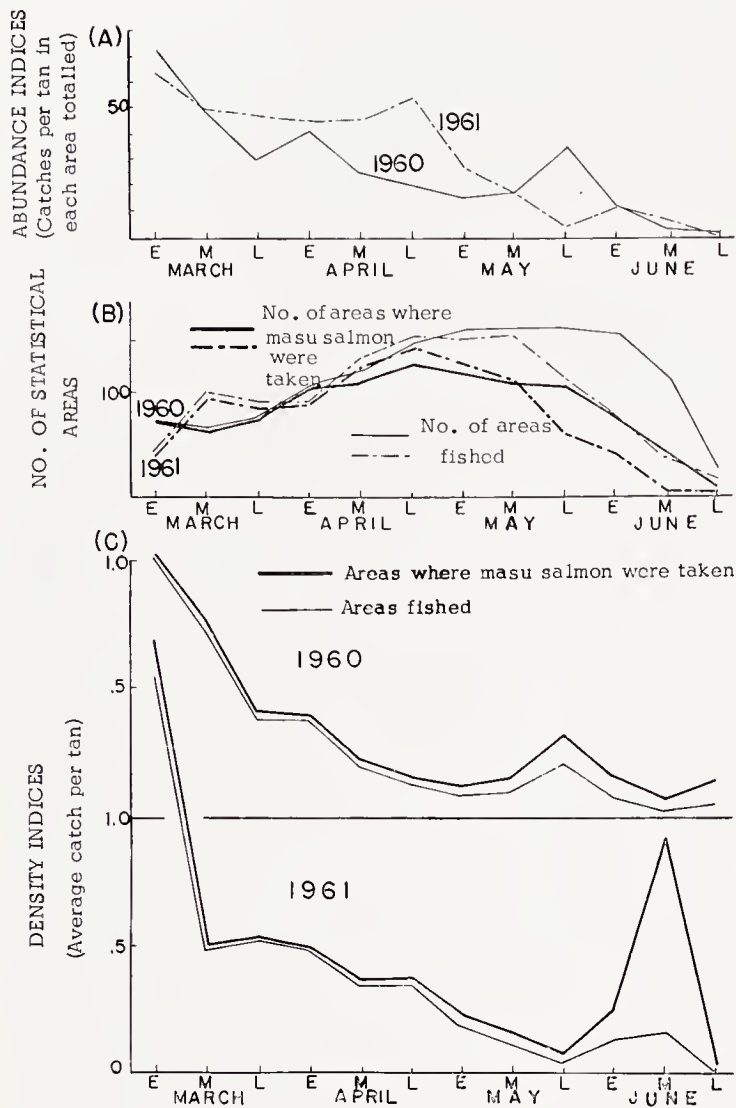


FIGURE 5. Seasonal changes in masu salmon abundance indices (A), seasonal changes in number of statistical areas fished (B), and seasonal changes in density indices (C), based on catch statistics of the Japan Sea salmon drift gillnet fisheries, March to June, 1960 and 1961.

The change in availability might be attributed partly to the fact that the fishing ground does not cover the whole area of the distribution of stocks and partly because some of the stocks may emigrate from the fishing grounds. In addition, there may be a change in the ecology of the fish and, as a result, the fish might then migrate at a greater depth from the surface. As mentioned before, these drift gillnet fisheries in the Sea of Japan depend mainly on pink salmon. However, in the earlier part of the season, the low abundance of pink salmon makes masu salmon relatively important. During March, the fishermen concentrate their efforts on fishing for masu salmon. As a result, it is quite possible that the fishing grounds for these drift gillnet fisheries are situated in March so as to favour the catching of masu salmon, while during April and May, when the pink

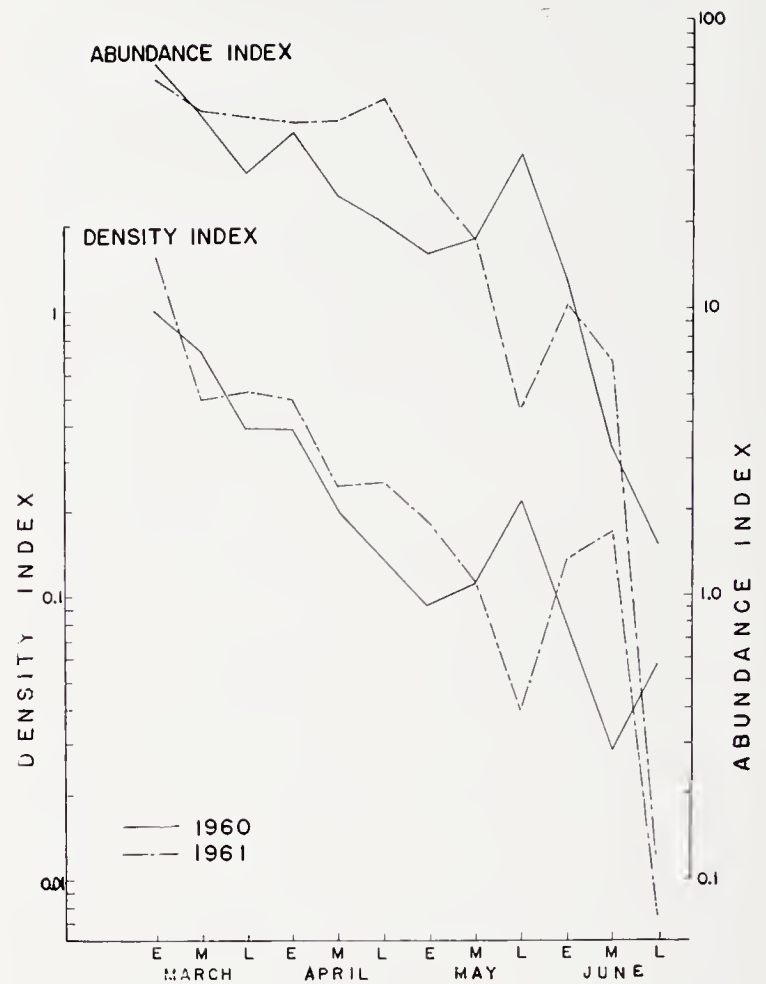


FIGURE 6. Seasonal fluctuations in abundance indices and density indices for masu salmon caught in the Japan Sea salmon fishing grounds. (This figure uses logarithmic scales to present the same data as are shown in Figure 5.)

salmon have become more abundant, the fishing grounds are located so as to favour the catching of pink salmon. Although the geographical distribution pattern of pink salmon is generally similar to that of masu salmon, there is a slight difference between them and, during the early part of the season, masu salmon tend to be distributed more southward than are pink salmon. The catch per tan indices for masu salmon have a tendency to be lower near the edge of the fishing ground (see section 3.3.1). This suggests that the area of distribution of masu salmon is, at least in the eastern half of the Sea of Japan, fairly well covered by the fisheries. As the season progresses, masu salmon begin to be caught by other types of gear in coastal waters closer to the coast than the area covered by the drift gillnet fisheries. In addition, at around this time some masu salmon are observed to enter the rivers. Therefore, it is evident that some masu salmon do emigrate from the drift gillnet fishing grounds. In any case, there is not sufficient information available to discuss the effects of the change in availability.

With regard to mesh selectivity, it is possible that during the earlier part of the season the fishermen may use gillnets with mesh sizes which are more favourable for catching masu salmon than those sizes used later in the season. However, there is no evidence to suggest that the fishermen change their mesh sizes according to the period of the season. In addition, the variation in mesh selectivity according to the species of salmon is not so critical that the fishermen can selectively fish different species by using nets with specific mesh sizes (Figure 3). Therefore, it is hard to believe that the effects of the variation in efficiency with differences in mesh sizes could be the main factors controlling the seasonal fluctuations in the abundance indices of masu salmon.

Finally, concerning the actual changes in the abundance of the stock, there is no doubt that the abundance does decrease in the later period of the season. This is partly because some of the masu salmon stocks migrate up the rivers and partly because of the loss due to fishing and natural mortality. However, it is still not known how well the apparent trend in the abundance indices represents the actual seasonal fluctuation in the abundance of the stock. In the areas from Hokkaido north, where the most productive streams are located, the runs of masu salmon do not appear in coastal waters earlier than May and most of them do not arrive until June or later. No information is available for estimating the natural mortality rate. It seems difficult, however, to explain, by mortality alone, this drastic decrease in abundance indices, which from early March to mid-May dropped to one-third or one-quarter of their initial values.

In conclusion, it is assumed that the seasonal decline in abundance indices can be largely attributed to a change in the availability of fish, particularly to their emigration from the fishing grounds. Further studies on the distribution of masu salmon in the coastal waters of Honshu, Japan, and in the western half of the Sea of Japan along the coast of North Korea and Primorskaia might help to clarify the situation.

Changes in the number of statistical areas occupied is assumed to reflect changes in the extent of the distribution of masu salmon stocks. The fishing grounds are concentrated in the southern part of the Sea of Japan during March and, as the season progresses, the northern boundary of the fishing grounds moves northwards. At the same time the total area of the fishing grounds is expanding. The changes in the areas of distribution of pink salmon and masu salmon might be reflected by such changes in the

fishing area. In the latter part of May, fish are less abundant and the fisheries are concentrated in the northern part of the Sea of Japan. The fishing season is over by the end of June.

The density indices of masu salmon vary by season in accordance with the seasonal fluctuations in abundance indices and the changes in the size of fishing grounds. In the earlier part of the fishing season, during March, the density indices decline very sharply until they are about one-third of the initial level. After this initial decline, the density indices continue to decline gradually at a rate which is approximately linear on the logarithmic scale until they reach minimum values at or near the end of the season. Occasionally, the density indices may even show a slight increase toward the end of the season. It is possible that this slight increase sometimes observed at the end of the season might be a result of statistical errors. Because the catch of masu salmon in this part of the season is very low, minor errors in statistics can have a relatively significant effect on the calculation of density indices⁸.

3.3 SPATIAL DISTRIBUTION OF CATCH PER TAN

3.3.1 *Changes in the density patterns of fish stocks by ten-day periods.* According to the analysis made in section 3.1.1, it is reasonable to assume that the number of fish caught per tan of gillnet is an indication of the relative abundance of fish in the area in question.⁹ Based on the number of fish caught per tan of gillnet in the 20 minute by 20 minute statistical areas and by ten-day periods, the distribution of masu salmon throughout the Sea of Japan and its seasonal changes were analyzed. The density distribution of masu salmon in the Sea of Japan based on catch per tan data is shown by ten-day periods for 1960 and 1961 in Figure 7. In order to show the concentration of salmon more clearly, the density indices were categorized into five groups for each ten-day period. These are areas which have a density more than approximately twice the average for that particular period, indicating a comparatively high density of fish; areas in which the density is less than one-fifth or one-tenth of the average for that particular period, indicating a very sparse distribution of fish; and three

⁸ Circumstantial evidence indicates that, in a few statistical areas, some of the catches of salmon have been misclassified as to species.

⁹ There are many problems besides that of mesh selectivity involved in representing the relative abundance of stocks by the catch per tan statistics. For example, since the drift gillnets fish only from the surface to a depth of approximately 6 m, the vertical distribution pattern of the fish affects the catch per tan statistics.

areas with densities between these two extremes. These five categories are depicted by different shading in Figure 7. The actual average catch per tan for

the whole area and the range of catch per tan for each of these five classes are given in individual figures for each ten-day period.

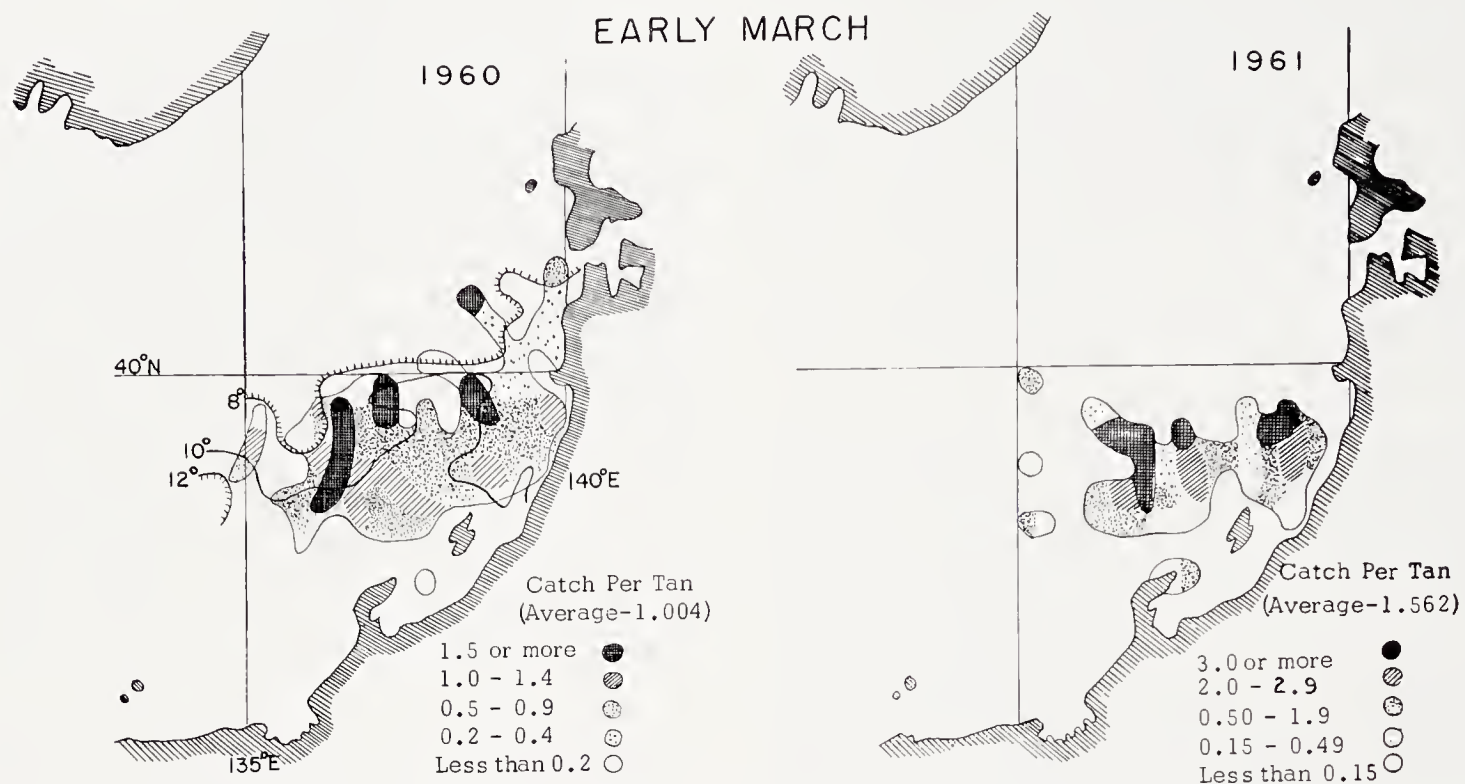


FIGURE 7. The density distribution (catch per tan) of masu salmon in offshore areas of the Sea of Japan and the distribution of surface water temperatures, by ten-day period, early March to mid-June, 1960, and early March to late May, 1961.

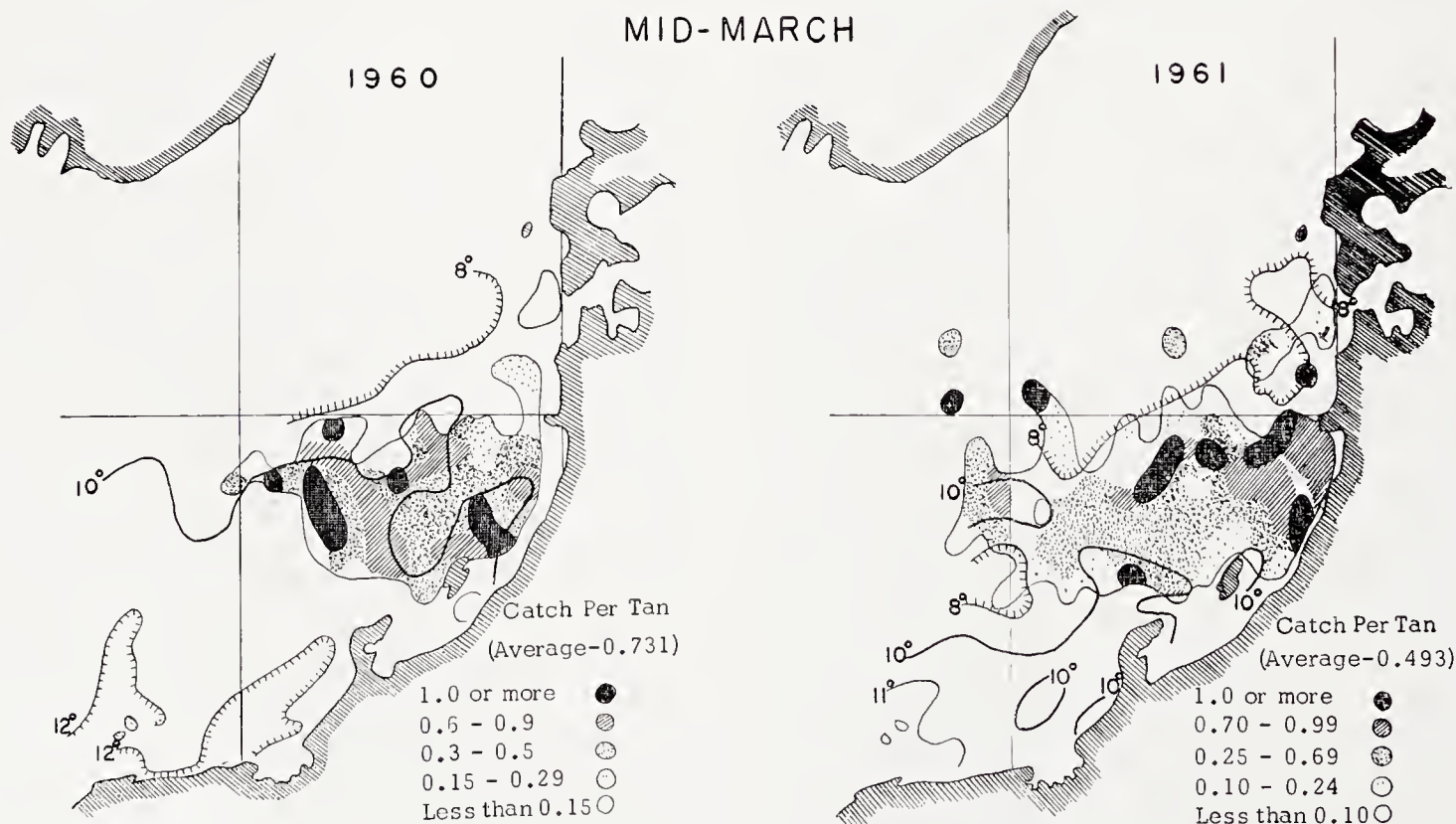


FIGURE 7. Continued.

Masu salmon are rather concentrated in the waters south of 40°N in the Sea of Japan during March and early April. After mid-April, the northern limit of distribution shifts rapidly northward and by mid-

May it reaches the northern tip of Hokkaido. On the other hand, the southern limit of distribution of masu salmon remains approximately along the latitude of 38°N during March and April and then shifts

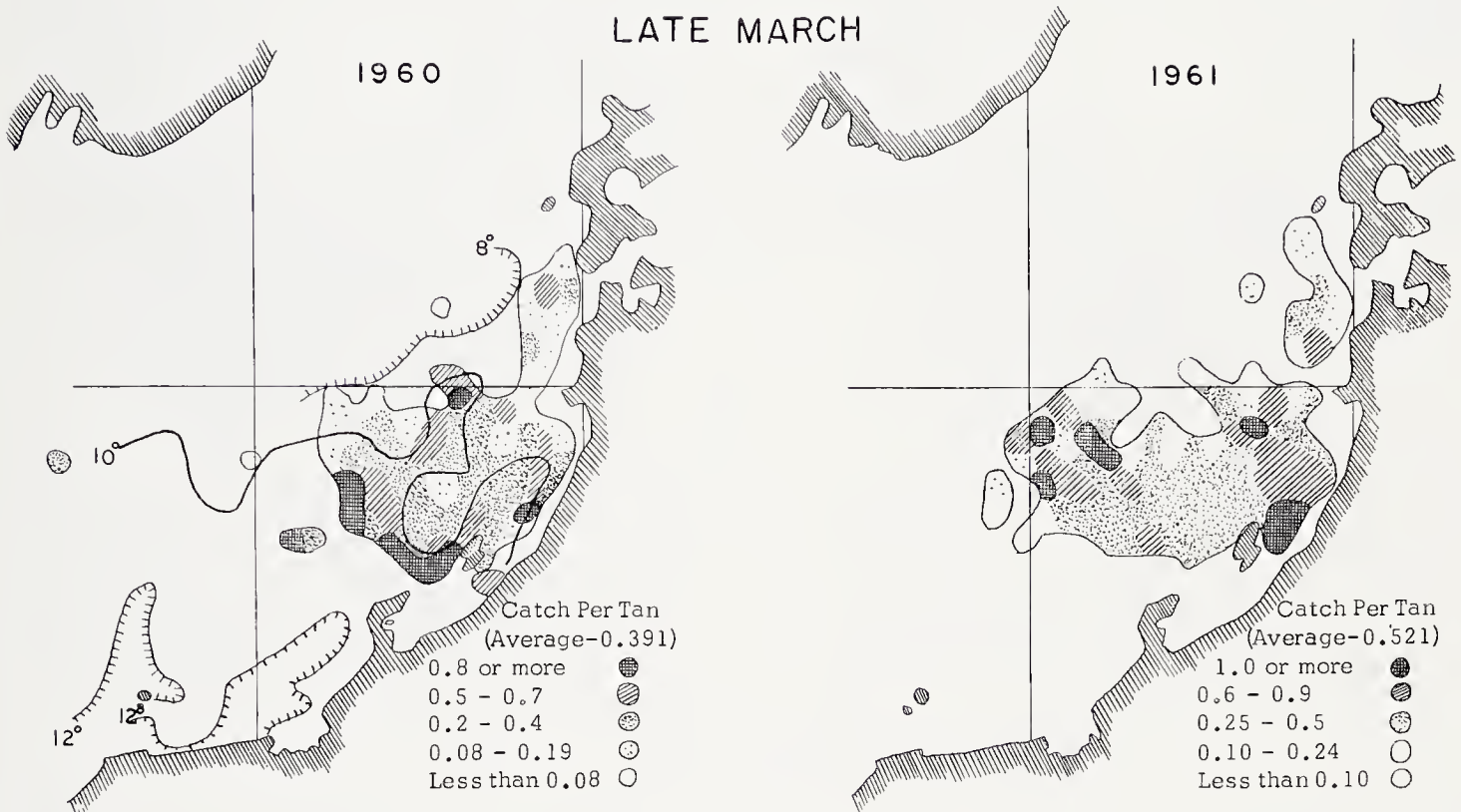


FIGURE 7. Continued.

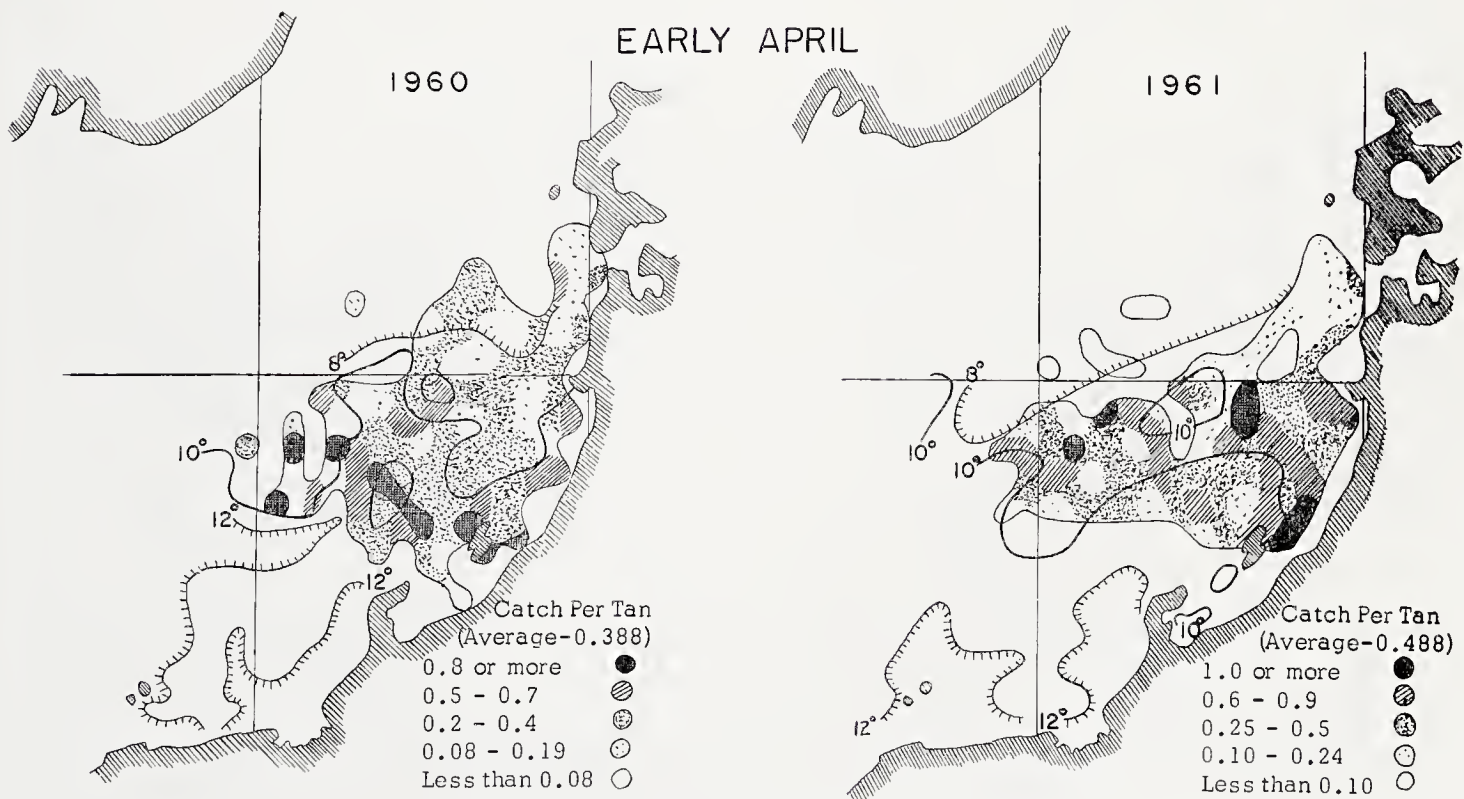


FIGURE 7. Continued.

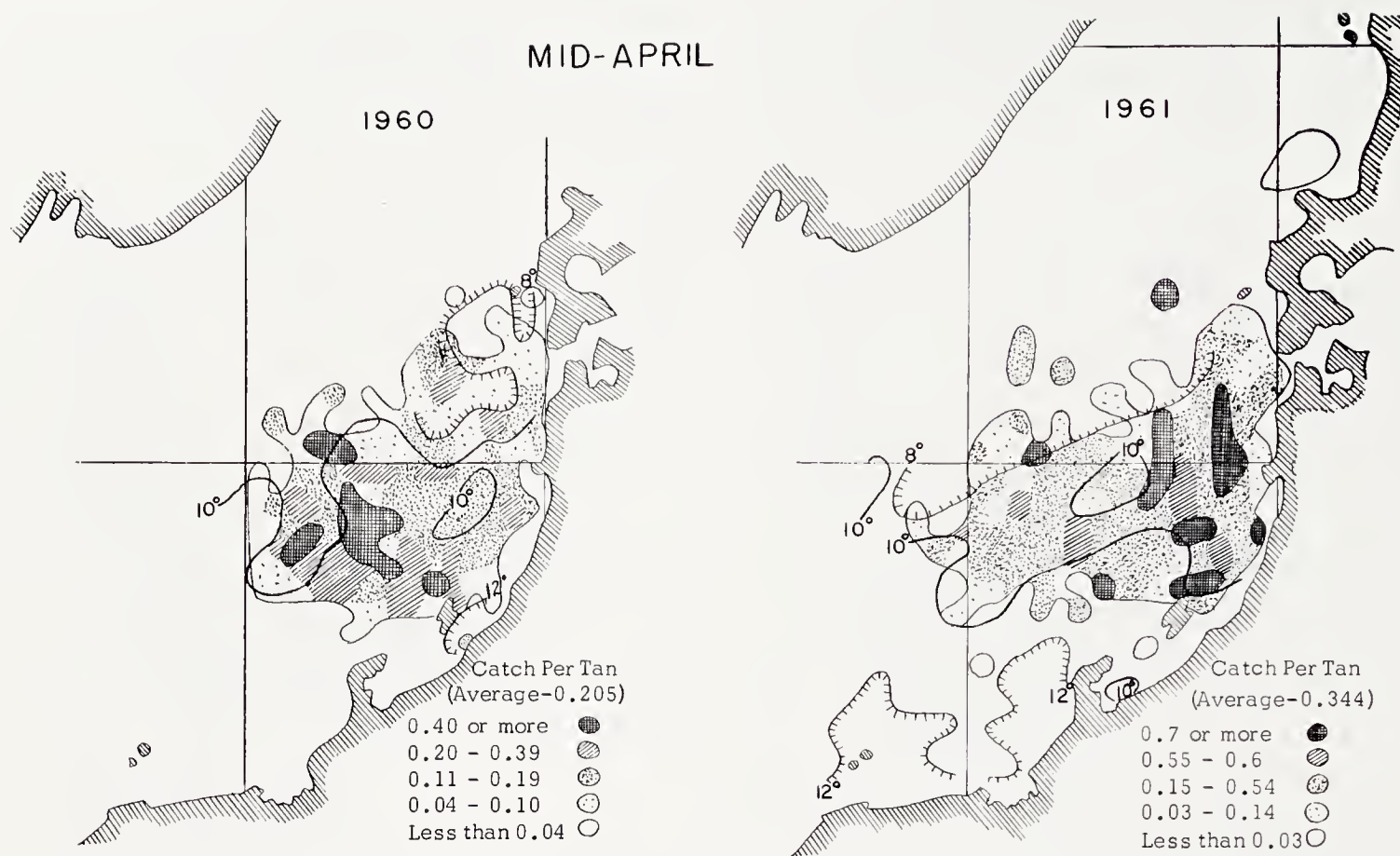


FIGURE 7. Continued.

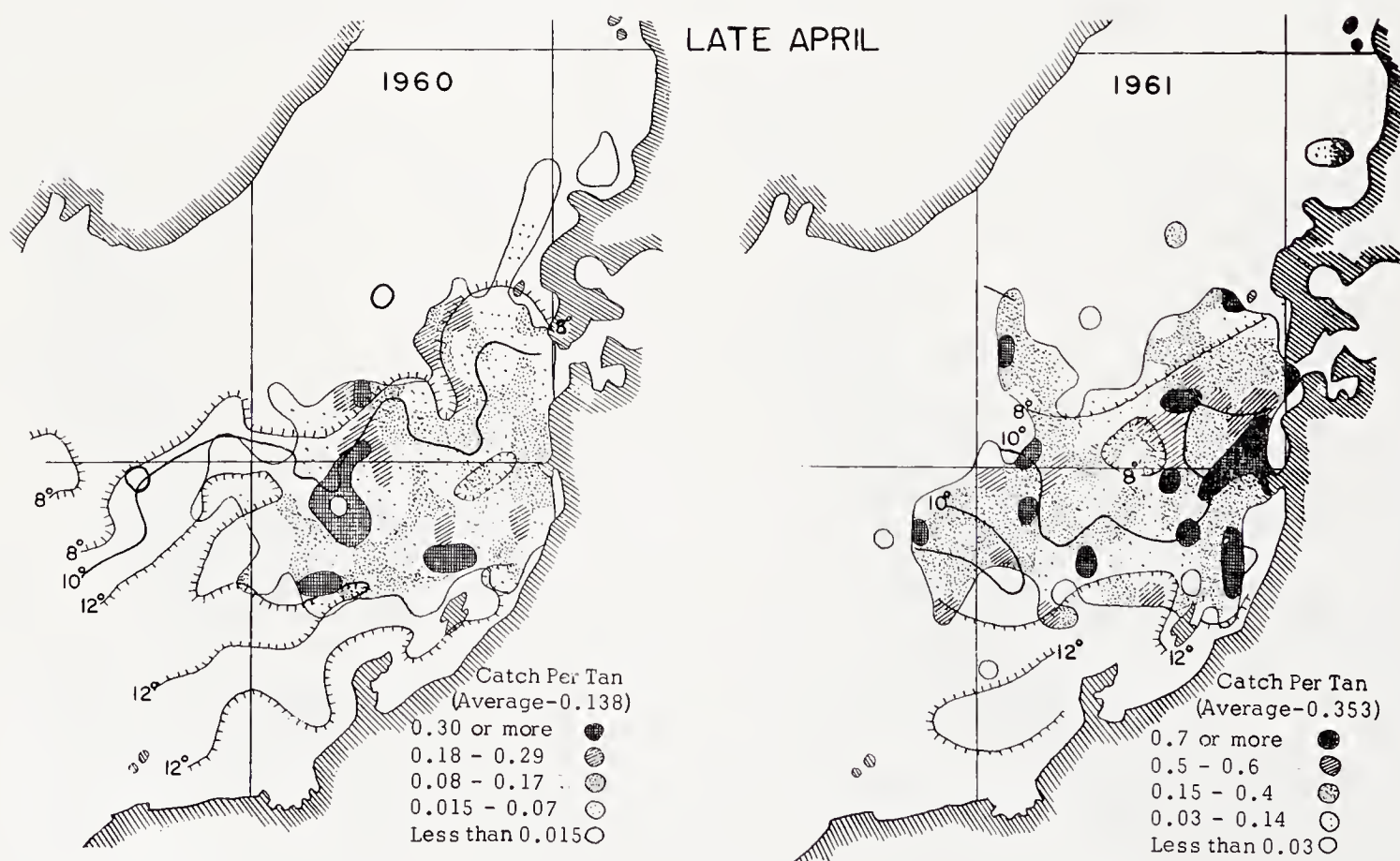


FIGURE 7. Continued.

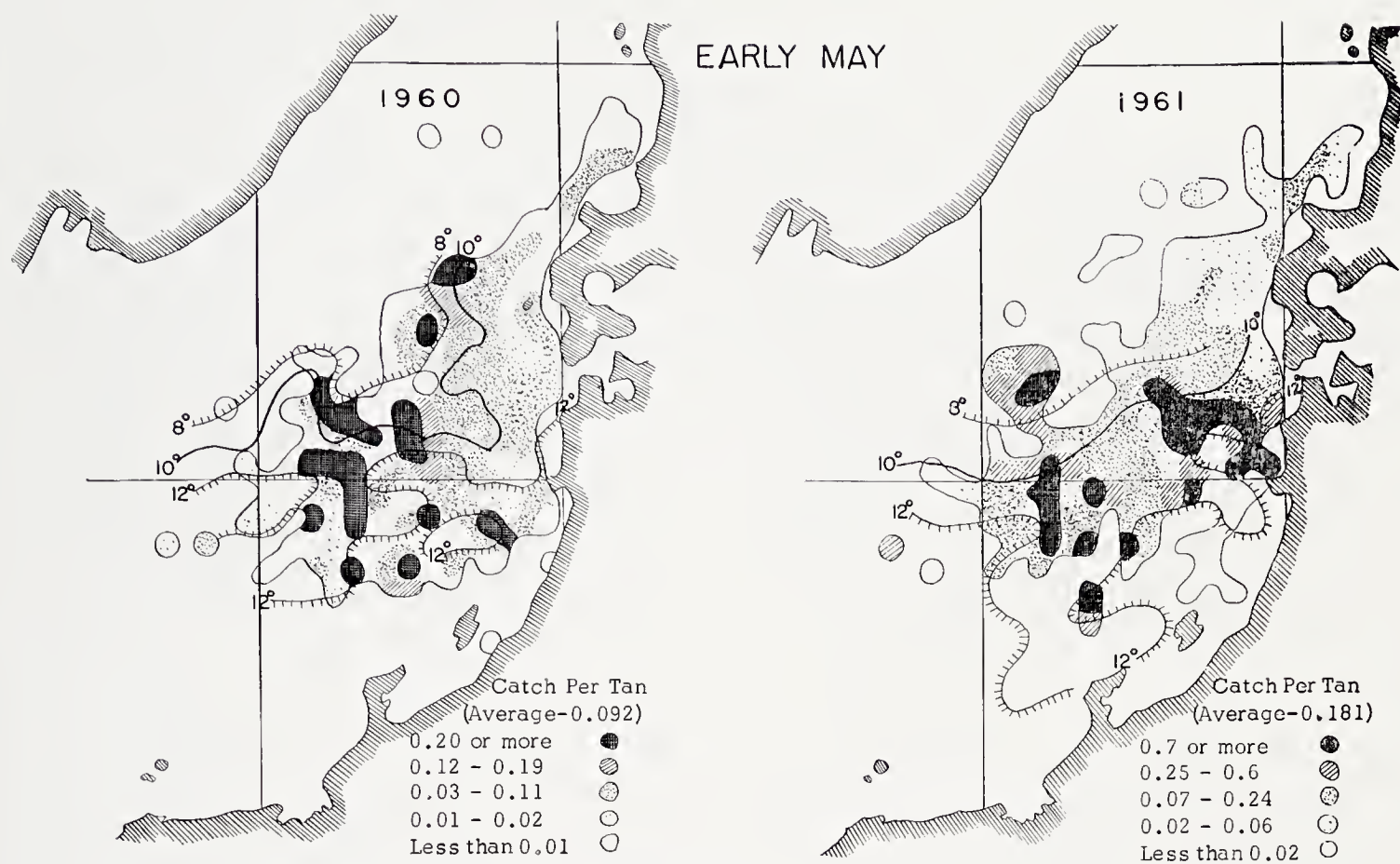


FIGURE 7. Continued.

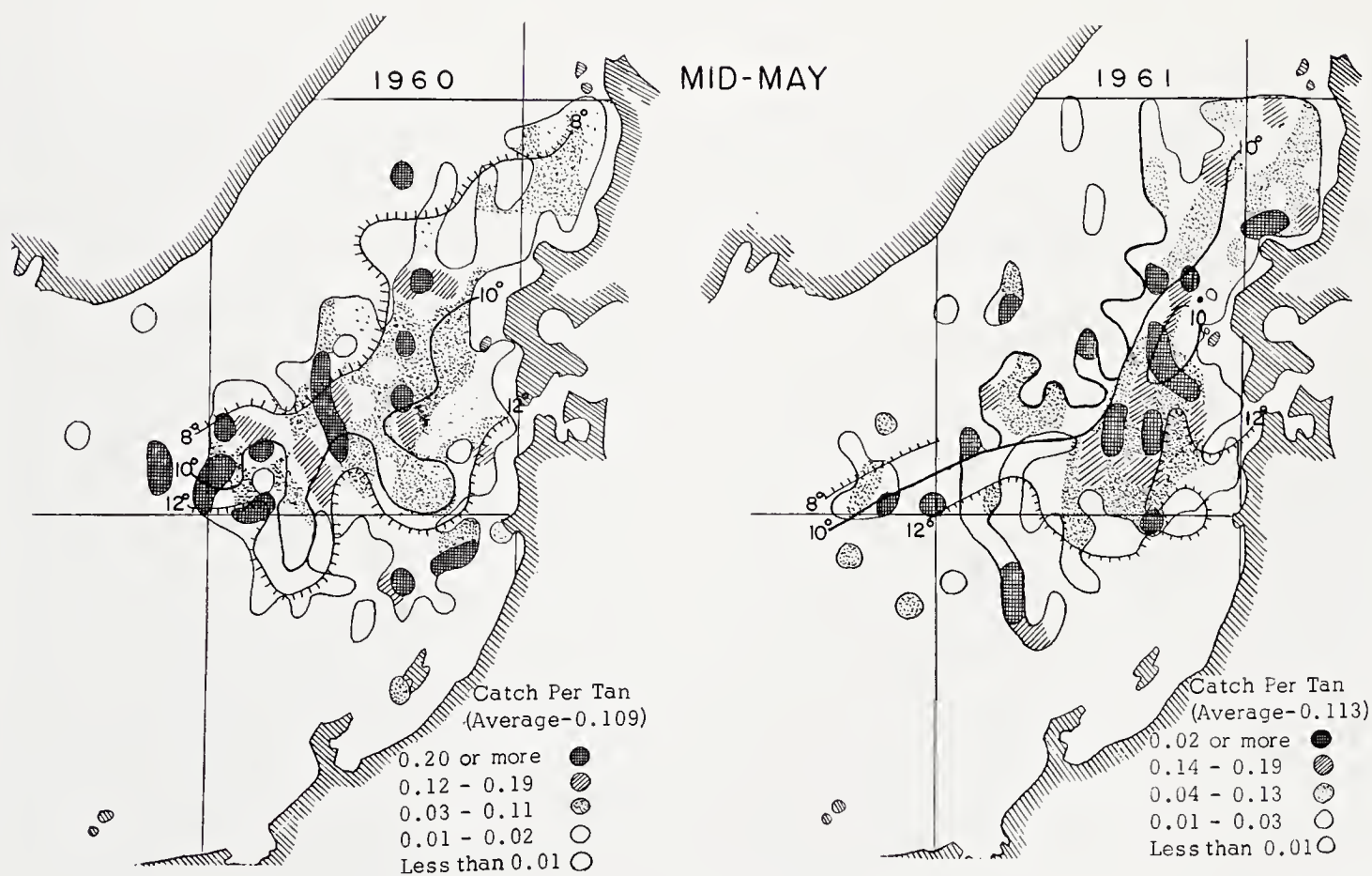


FIGURE 7. Continued.

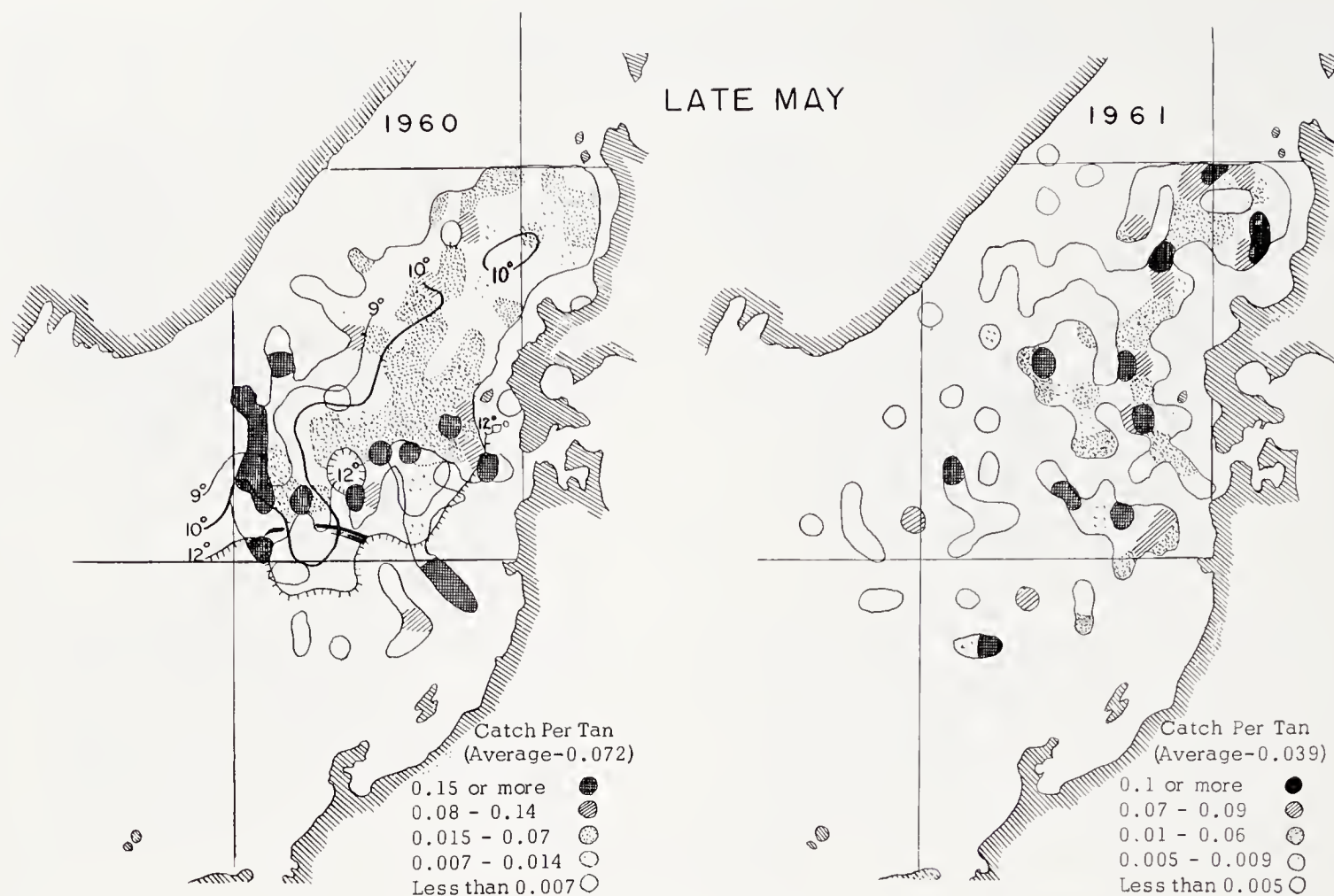


FIGURE 7. Continued.

northward during May. During June, the distribution first extends to the offshore waters of northern Hokkaido and then moves farther north. The distribution outlined above will be described in the following paragraphs in more detail by dividing the season into ten-day periods.

In early March, the fishing grounds are limited to the area between the latitudes of 38°N and 40°N, where the catch per tan values are quite high. In much of this area, catches of one or more fish per tan are recorded. In this period, there is some tendency for the major concentration of masu salmon to be located in waters somewhat towards the north of the fishing grounds. The area covered by the fishing grounds was elongated in an east-west direction and extended as far west as 135°E. However, there are no clear indications that the relative abundance of masu salmon decreases as one moves towards the west. Therefore, it is suspected that masu salmon are distributed farther west than the western extent of the fishing grounds. The distribution of the surface water temperature at this time also supports this assumption (see section 3.4.1).

In mid and late March, there is a slight tendency for the fishing area to expand, but most of the fishing grounds are limited to the area between 38°N and 40°N and east of 135°E. The relative abundance is still fairly high, but the values are lower than those recorded in early March for almost all the statistical areas in which fishing occurs. However, it is also noted that in an area near the northeast coast of Sado Island an even higher level of catch per tan was recorded. In the waters east of 139°E, the fishing grounds extend farther north, as far as the west coast of southern Hokkaido. The catch per tan values in this northern area are relatively low compared to the values for the fisheries located in more southern waters. In late March of both 1960 and 1961, there were two concentrations of masu salmon. One was in an area extending from northeast of Sado Island to close to the coast of Honshu and the other was in waters which extended from northwest of Sado Island to around 39°N and 136°E. These two separate concentrations could be followed in and after early April.

In April, the extension of fishing grounds into the

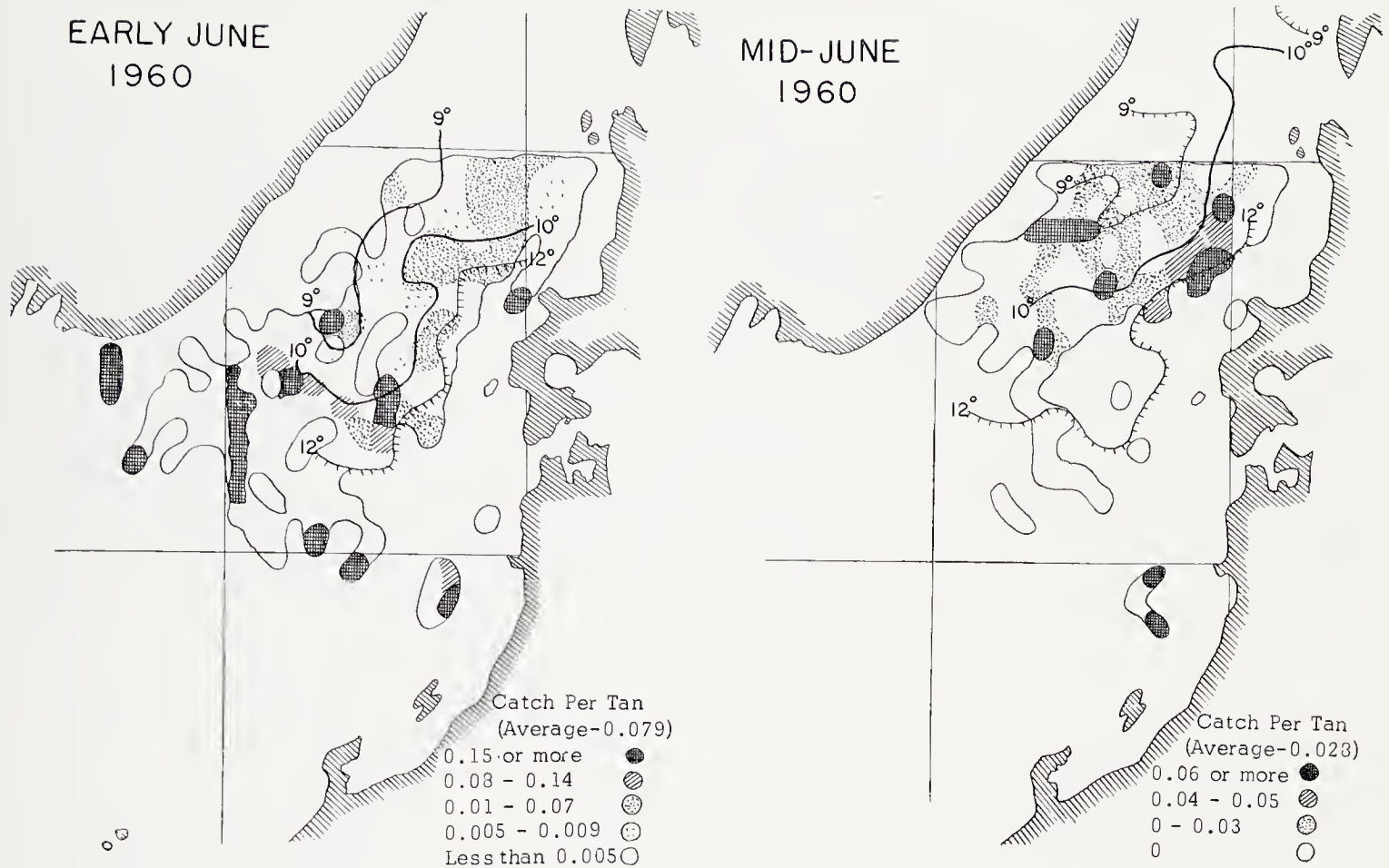


FIGURE 7. Continued.

area north of 40°N gradually becomes more marked. In late April, the fishing grounds are in waters south of a line connecting Okujiri Island with the point at 40°N and 135°E . On the other hand, the southern limit is still approximately along the latitude of 38°N . The western boundary of the fishing grounds is essentially still located along the longitude of 135°E , although some fishing operations were carried out near 134°E in 1961. The average catch per tan declines during this period to even less than 0.5 fish per tan. In late April, average values of 0.14 fish per tan in 1960 and 0.35 fish per tan in 1961 were recorded. This decline in density can be explained partly by the expansion of the area of distribution of masu salmon which was represented by an increase in the area covered by the fishery. The high concentrations of masu salmon in areas northeast and northwest of Sado Island remained, although they showed some northward movement during April. In early April, the areas of high relative abundance of masu salmon are still south of 40°N , while in late April they are both north and south of 40°N . However, the relative abundance has decreased considerably by late April. The concentration of masu salmon located in the area northwest of Sado Island moves northward in

the offshore waters of the island, while the other concentration in the area northeast of Sado Island migrates northward in coastal waters. In 1960, the relative abundance of the concentration to the northwest of Sado Island was higher than that of the concentration to the northeast of the island. In 1961, the reverse was true. This seems to be reflected by the much lower catches per tan recorded in the coastal waters in 1960 than in 1961.

In May, the fishing grounds extend farther northward along the coast of Hokkaido and by mid-May they are located in waters south of the line connecting Rishiri Island with 42°N and 135°E . During the last ten-day period in May, the fisheries cover all the area in the northern part of the Sea of Japan except the waters adjacent to Primorskaia. In early May, relatively high concentrations of masu salmon can still be observed between latitudes 38°N and 40°N . However, by mid-May the catches of masu salmon per tan have, with a few exceptions, declined markedly in the waters south of 40°N , and during late May very few fishing operations are carried out in these waters. Some vessels fish as far west as 133°E , but the fishing in the western part of the fishing grounds

is rather sporadic and, in addition, the catches are very variable. As a result, the distribution pattern of masu salmon in this part of the fishing grounds is not well represented by the catch statistics. However, some remarkably large catches of masu salmon per tan of gillnet were recorded at several locations in this area. This suggests that if no statistical errors are involved then there is a fairly high abundance of masu salmon in the area west of 136°E . Apparently, the concentrations of masu salmon which pass through the offshore waters of Okujiri Island and then those of Rishiri Island continue to move northward. However, it is also assumed that the significant part of the other concentration, which has moved northward along the longitude of 136°E , has left the offshore fishing grounds for the waters near Primorskaia by this time.

In 1961, the abundance of masu salmon declined

very sharply in late May and the catches during June were very small. Because of this, the relative abundance of masu salmon for June of 1961 is not shown in Figure 7. On the other hand, in 1960, masu salmon were still relatively abundant at the end of June. The center of distribution was located off the west coast of northern Hokkaido, and sporadic high catch per tan values were recorded in all the fishing grounds north of 39°N . This might indicate that many small stocks remained dispersed in a broad area after most of the stocks had left the fishing grounds and moved towards the north.

3.3.2 *Change in catch per tan by ten-day period in each of the statistical areas.* In section 3.3.1, the distribution patterns of fish stocks were compared for ten-day periods. The average catch per tan declined rather markedly from the maximum recorded in early March. As a result, an area designated as a low-

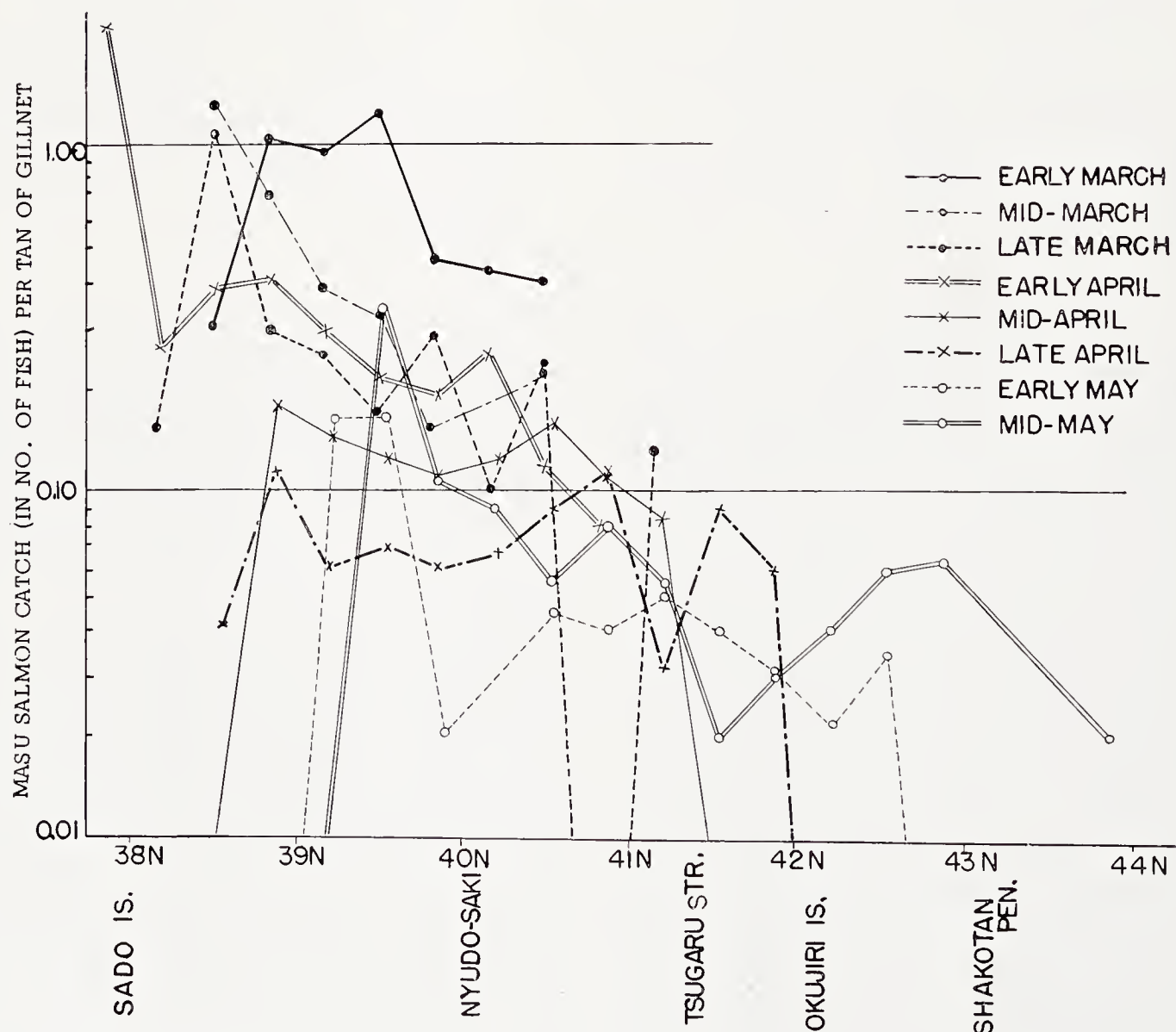


FIGURE 8. Seasonal fluctuations in the density distribution of masu salmon along the meridian of 139°E longitude, 1960.

abundance area might have a higher catch per tan in one ten-day period than that recorded at a later date in an area designated as a high-abundance area. For instance, a catch per tan of 0.15 or less depicted an area of very low relative abundance for the first ten-day period in March 1961, while a catch per tan of 0.10 or more depicted an area of very high relative abundance for the last ten days of May 1961 (Figure 7). Thus, there is a danger that we did not properly understand the seasonal fluctuations in the density of the fish stocks. After considering these points, in this section the changes in catches per tan for a specific area are followed through the season.

The catch per tan recorded in the statistical areas along longitude 139°E (strictly speaking, this was the average of the values obtained for the statistical areas between 138°40'E and 139°E, and between 139°E and

139°20'E) in successive ten-day periods are shown in Figures 8 and 9 for 1960 and 1961, respectively. In these figures, the symbols connected by lines represent the changes in density from south to north for specific ten-day periods, and the symbols on a particular latitude (on abscissa) represent the changes in the density through the season at that latitude.

Since both the longitudinal and seasonal fluctuations were quite consistent for the years 1960 and 1961, the data from these two years are combined. High catch per tan values were recorded during early March for the areas between 39°N and 40°N and the values for the areas outside of these latitudes were progressively lower. In mid and late March, the catches per tan recorded for the area between 39°N and 40°N decreased, while the catches per tan for the areas close to the shore and south of 39°N increased.

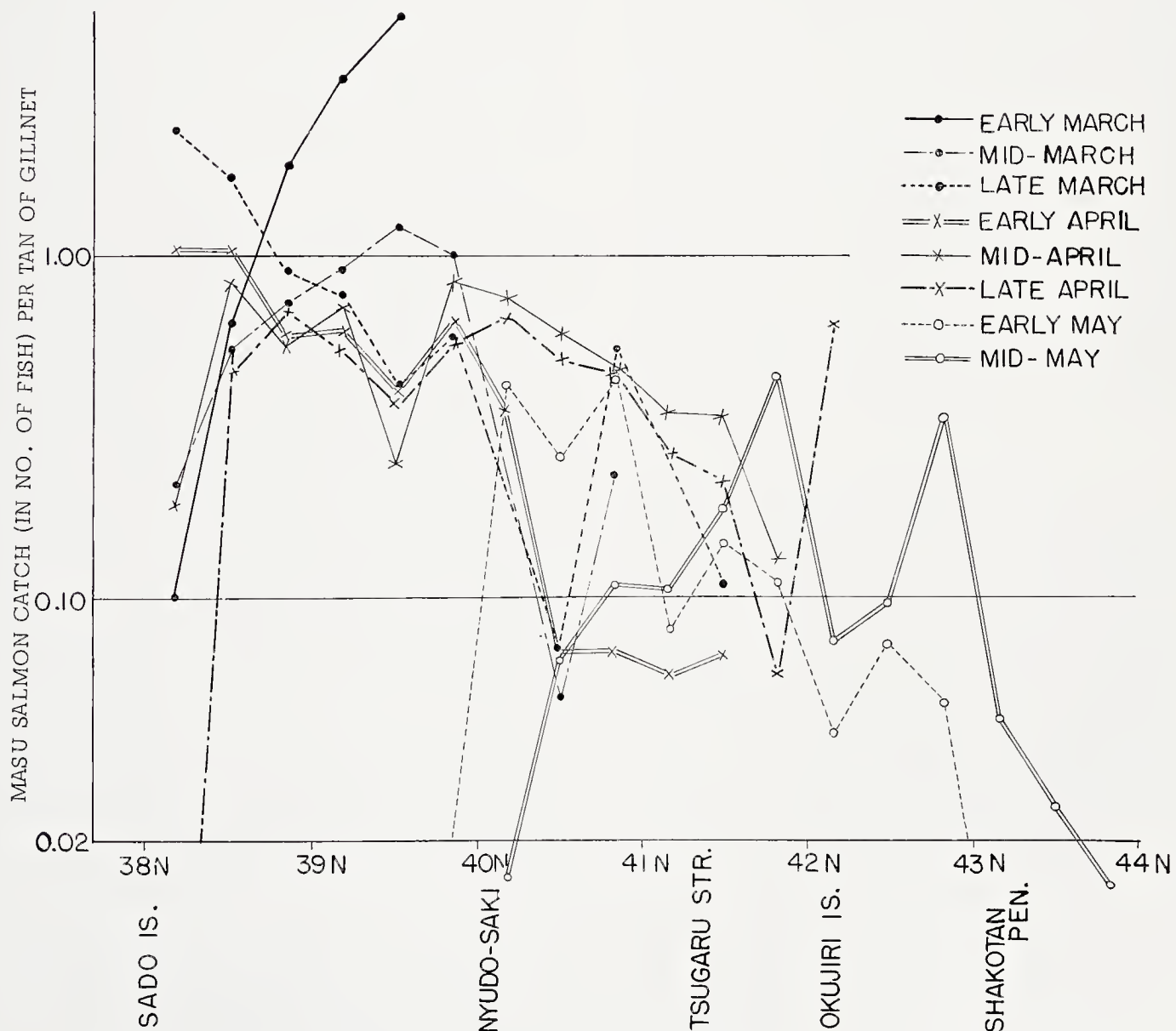


FIGURE 9. Seasonal fluctuations in the density distribution of masu salmon along the meridian of 139°E longitude, 1961.

TABLE 20. Changes in the density distribution of masu salmon along 139°E longitude.

Ten-day period	Location of the southern concentration	Maximum density	Location of the northern concentration	Maximum density	Abundance of masu between these two concentrations
		<i>No. of fish/tan</i>		<i>No. of fish/tan</i>	
late March	38°20'–38°40'	1.05	39°40'–40°00'	0.28	4.05
early April	38°40'–39°00'	0.41	40°00'–40°20'	0.25	2.69
mid-April	" – "	0.18	40°20'–40°40'	0.16	1.68
late April	" – "	0.12	40°40'–41°00'	0.12	1.15
early May	39°00'–39°40'	0.16	41°00'–41°20'	0.05	1.02

This indicates that the fish migrated southwards during March. During the period between early April and early May, the area where relatively high catches per tan were recorded shifted northwards as time progressed and the value for specific statistical areas south of 41°N generally decreased. Therefore, the pattern observed from the distribution of the catch per tan data does not indicate a northward migration of a mass of fish, but rather that the gradual disappearance of fish from the southern areas leaves a relatively high abundance at this time in the northern areas. This general pattern can be related to areas other than those along 139°E. In the region north of 41°N, some statistical areas showed an increase in the catch per tan figures towards mid-May. The values were high in these areas particularly in mid-May. However, in most areas, the catch per tan for mid-May did not exceed 0.1 fish and the wide variation in values made it difficult to detect any general tendencies.

As can be observed in Figure 7, the concentration of fish stocks shifted northward along 139°E during the season in both 1960 and 1961. However, it became clear that the areas in which high catches per tan were recorded did not move northwards as a unit. In other words, fish were disappearing from all the fishing grounds rather rapidly. The set of figures which shows the seasonal changes in the catch per tan values for the period between late March and early May 1960 is a good example to show this disappearance. The catch per tan values along 139°E for late March show that there are two high concentrations of masu salmon in the area. The first is between 38°20'N and 38°40'N and the second is between 39°40'N and 40°N. These two separate concentrations were maintained even in and after early April and they did shift gradually northwards. At the same time, however, the catches per tan in these areas of concentration decreased. The locations of the two concentrations of masu salmon are shown by ten-day periods in Table 20. The catch per tan

values for the areas of concentration and the abundance indices between two peaks which equal the sum of the catches per tan recorded in the areas between these two peaks are also shown for these periods. From late March to early May, a period of approximately 40 days, the locations of the highest catches moved northwards about 1° in latitude, while the abundance decreased to approximately one-quarter the initial level. It is also noted that the rate of decrease in abundance was fairly consistent from late March to late April. It apparently decreased by about one-third over each ten-day period.

The data referred to here are those recorded in the area extending north and south within 20 minutes from 139°E longitude. The same general tendency can be observed in areas along other longitudes as well. In section 3.3.1, the northward shift of the concentrations was discussed and, as indicated there, this shift cannot be interpreted as a simple migration of the high concentrations northwards. If we can assume that the decrease in the value of the abundance indices by a factor of one-third every ten days is due to mortality, then the fact that the areas with a relatively high abundance continue to be located farther north can be interpreted as due to the northward migration of fish. The fact that the distribution pattern, with its two peaks, remains similar for a period further supports the interpretation. However, if the decrease in the abundance of fish was a result of other factors, such as the emigration of fish, then the northward shifting of the relatively high concentrations does not necessarily have to be interpreted as being due to the northward migration of masu salmon.

3.4 THE RELATIONSHIP BETWEEN THE DISTRIBUTION PATTERN OF STOCKS OF MASU SALMON AND OCEANOGRAPHIC CONDITIONS

3.4.1 *Distribution pattern of masu salmon stocks with respect to surface water temperature.* Oceanographic

observations have been conducted during the salmon drift gillnet fishing season in the Sea of Japan. These data made it possible to construct isotherms of the surface water temperature for each ten-day period (Japan Sea Reg. Fish. Res. Lab., unpub.). Although it is not well known in what layers masu salmon are migrating, the distribution of the relative abundance indices of masu salmon is compared here with the distribution of the surface water temperature on the basis of ten-day periods. In Figure 7, the catch per tan of masu salmon in the Sea of Japan is shown by ten-day periods along with the surface isotherms of 8°C, 10°C and 12°C. In a few parts of Figure 7, the 9°C isotherm is given in place of the 8°C isotherm and in other cases the 11°C isotherm is used instead of the 12°C isotherm.

A fairly close relationship was noticed between the distribution of the surface water temperature and the relative abundance of masu salmon. The drift gillnet fishing season lasts from March to June, inclusive, and throughout the 1960 and 1961 seasons very few relatively high catches per tan were made in waters where the surface temperature was below 8°C. High catch per tan values were also exceptional in waters with surface temperatures over 12°C. Therefore, it can be safely concluded that the major proportion of the masu salmon stocks was distributed in waters having a surface temperature between 8°C and 12°C. In the Sea of Japan, the area where the surface water temperature is approximately 10°C (8°C to 12°C) corresponds to the Polar Front, where the cold water masses coming down from the northern part of the Sea of Japan encounter the warm Tsushima current from more southern parts and form a very complicated oceanic pattern. Between March and June, this Polar Front gradually moves northward. At the same time, the concentration of masu salmon moves northward, approximately following the surface isotherm of 10°C. Thus, it is concluded that the movement of these fish is closely related to the movement of the Polar Front.

Although it has been concluded that the distribution of masu salmon is generally limited to waters with a surface temperature of 8°C to 12°C, it does not necessarily mean that masu salmon will be present in all the areas that have a surface water temperature between 8°C and 12°C. For example, during March and April, the surface isotherm of 12°C is located far southwest of the fishing grounds and also probably far south of the southern limit of masu salmon distribution. However, the southern limit of masu salmon distribution does shift northward in May, as if the fish were pushed northwards by the 12°C isotherms.

During March, very few fish are distributed in waters north of the 8°C surface isotherm; in April, however, when the fish are starting their northward migration, part of the stocks cross this isotherm to areas where the surface temperature is even lower. It might not be appropriate to relate the distribution pattern of masu salmon with surface water temperature, since masu salmon do not necessarily migrate in the surface layer of the ocean. Even disregarding this problem, it is evident that the relationship between the distribution of masu salmon and oceanographic conditions is not a simple one.

Several isolated cold-water masses surrounded by gyres occur along the Polar Front zone. In some instances, the distribution pattern of masu salmon is closely related to the presence of these gyres. In Figure 10, the distribution pattern of masu salmon density indices for late March 1960 was compared with the computed currents (Japan Sea Reg. Fish. Res. Lab., unpub.). In the waters north of Sado Island, two gyres, one with a clockwise current and another with an anti-clockwise current, were observed. A relatively high abundance of masu salmon was found on the east, south and west sides of the gyres. However, this kind of correspondence is not consistent and it is not adequate enough to derive any conclusions about the relationship between the circulation of the water and the distribution pattern of fish.

3.4.2 *Distribution pattern of fish stocks with respect to vertical distribution of water temperature.* The distribution pattern of masu salmon should be related not only to

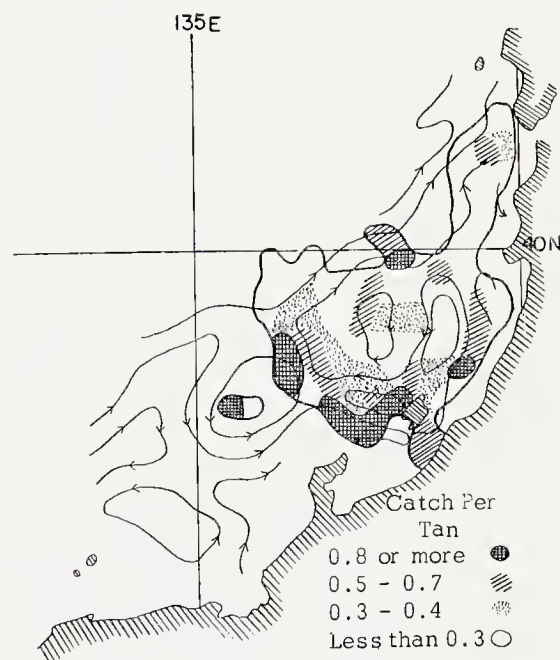


FIGURE 10. The density distribution of masu salmon and the computed current system in late March, 1960.

the horizontal distribution of water temperature but also to the vertical distribution of water temperature. Also, it is assumed that the availability of fish is often affected by the vertical distribution of water temperature. For example, it is to be expected that the availability of fish to drift gillnets, which fish only in the surface layer of the ocean, might increase when the depth of the thermocline from the surface decreases and causes the fish to congregate in the surface layers. Therefore, it is interesting to compare the distribution pattern of fish stocks or the catch per unit of effort with the vertical distribution of water temperature.

Oceanographic observations made during the salmon fishing season in the Sea of Japan provided data on the water temperatures at various depths from the surface of the ocean. These data could be used to make vertical profiles of the water temperature distribution. Here, two profiles of the vertical distribution of water temperature which were prepared by the Japan Sea Regional Fisheries Research Laboratory were taken for examples and were compared with

the catches per tan recorded in the same ten-day periods for statistical areas near the lines along which the vertical profiles were taken. The localities of these lines, the oceanographic stations and the statistical areas which were used for comparisons with catches per tan are shown in Figure 11. The temperature profiles along these lines and the corresponding masu salmon catches per tan are shown in Figures 12 and 13. Figure 12 was prepared from observations made at Stations 37 to 52 in the period between April 28 and 30, 1960; consequently, the catch per tan figures are those for late April of the same year. Figure 13 is prepared from observations made between May 2 and 4, 1960, at Stations 65–71, the catch per tan data being for early May of the same year. The localities against which the catch per tan data were plotted were the points at which perpendicular lines drawn from the center of each statistical area touched the line of oceanographic observation. In addition, the computed current systems prepared by the Japan Sea Regional Fisheries Research Laboratory are shown in Figure 11, in

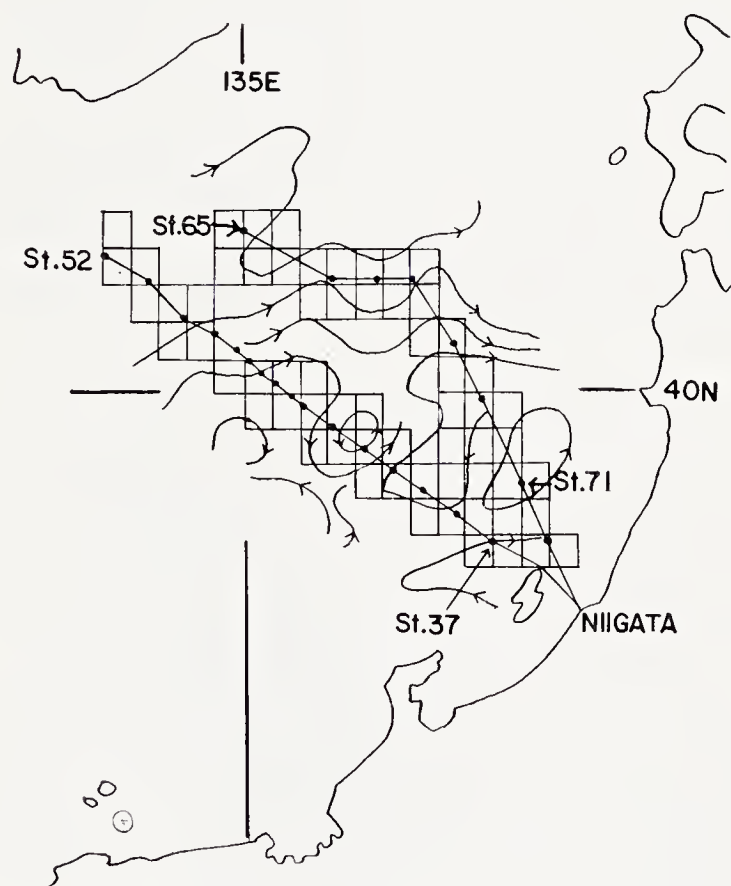


FIGURE 11. Oceanographic observation stations, the line along which the vertical profile of the water temperature was prepared and the statistical areas which were used for comparison of density distribution with oceanographic conditions and the computed current system. Late April to early May 1960. (Refer to Figures 12 and 13.)

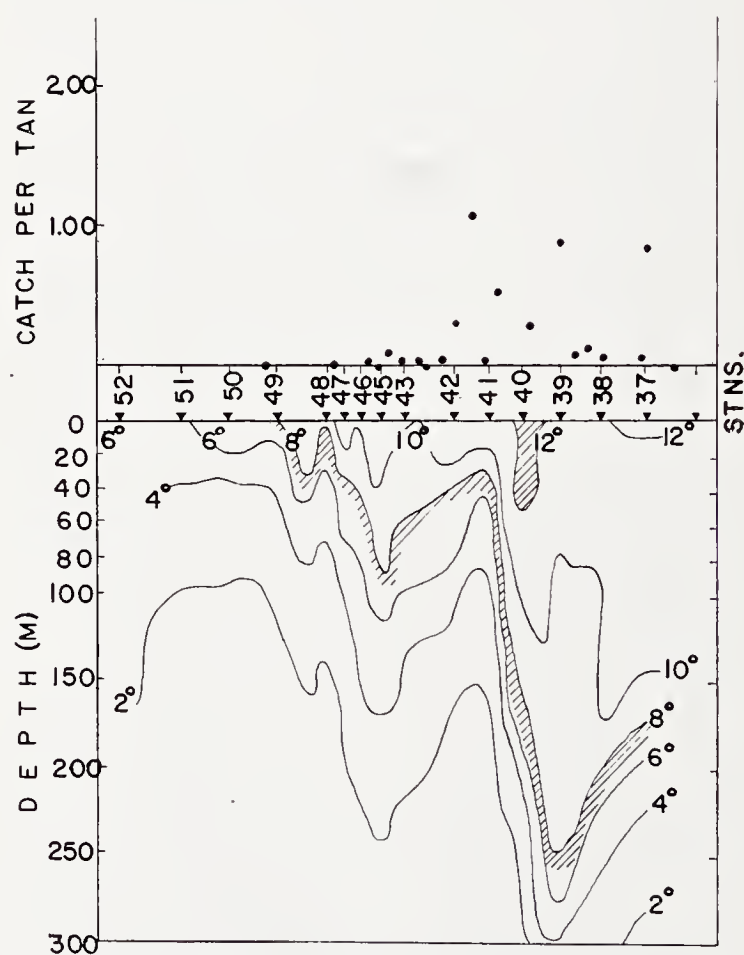


FIGURE 12. A vertical profile of water temperatures (lower figure) and the catch per tan recorded along the profile line (upper figure). (The line along which the profile was prepared is shown in Figure 11. Data for late April 1960.)

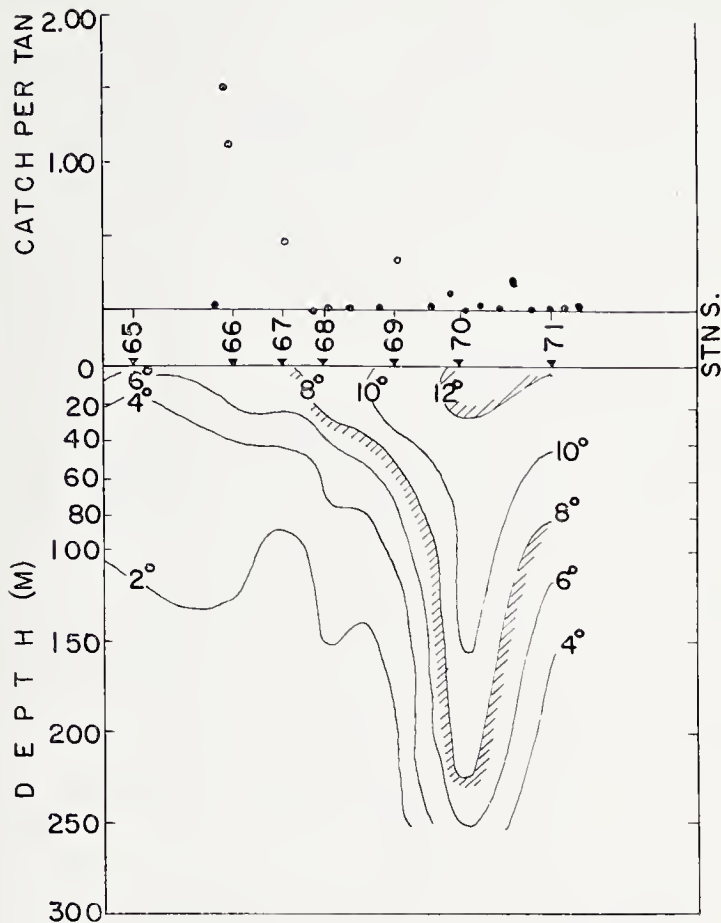


FIGURE 13. A vertical profile of water temperatures (lower figure) and the catch per tan recorded along the profile line (upper figure). (The line along which the profile was prepared is shown in Figure 11. Data for early May 1960).

order to relate the current systems with these profiles.¹⁰

As is shown in Figure 12, the highest catch per tan values were recorded near Stations 39 to 42, where the vertical distribution of water temperature is very characteristic. The vicinity of Stations 39, 40 and 41 was an area where northward currents predominated and a sharp gradient in water temperature existed between a warmer water mass on the eastern side and a cooler water mass on the western side. In Figure 7, the catch per tan data in late April indicate that the relatively high abundance of fish present in the area near Stations 39 to 42 extended towards the north to Stations 67 and 68 and formed a narrow band of high abundance lying in a south-north direction. It is clear from Figure 13 that this characteristic structure of the water mass observed near Station 40

extended to the northeast almost as far as Station 70. However, the relatively high abundance of masu salmon near Station 70 is sporadic. As is shown in Figure 13, a relatively high concentration of masu salmon was located near Stations 66 and 67, where warmer water extends northward in the surface layer, resulting in a temperature stratification. Also, in this area the currents meander, but still show a generally eastward flow.

It is difficult to define precisely the relationship of the distribution pattern of masu salmon with the vertical distribution of water temperature or with the current system on the basis of only the two above-stated instances. It is necessary that further studies be carried out before any generalizations are made.

3.5 FORK LENGTH COMPOSITION

3.5.1 Difference in fork length according to sex. Samples taken in 1955 near Okujiri Island indicated the existence of a difference in masu salmon size according to sex (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956). The female masu salmon were, on the average, larger than the males. This contrasts with pink salmon, where the males tend to be larger. Differences in size according to sex can introduce large errors in results of size composition analysis of masu salmon. In the case of pink salmon, it is well known that the catch during the earlier part of the season consists predominantly of males, while later in the season females are predominant in the catches. Since this may also be characteristic for masu salmon (see section 2.6.4 and Table 18), it may make it more difficult to accurately analyze the changes in size composition with respect to time. To avoid such errors, the fork length composition by sex was carefully studied to verify the presence or absence of sexual dimorphism.

In Figure 14, the fork length frequencies according to sex are shown for masu salmon caught with gillnets in waters near Okujiri Island by the Hokkaido Prefectural Fisheries Experimental Station. Although the inadequacy of the sample does not permit any definite conclusions, there did not appear to be a consistent tendency for either sex to be larger than the other. It is probably accurate to state that the fork lengths of the males show greater variation than those of the females. Similar results were reported concerning the size of fish in catches in 1961 (Japan Sea Reg. Fish. Res. Lab., unpub.). The size composition for the catch of masu salmon in 1955 also suggested a greater variation in the sizes of males than in those of females (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956). In Table 21,

¹⁰ In Figure 11, the computed currents for late April were drawn near the observation line of late April and the computed currents for early May were drawn for the area close to the early May observation. Then those two current systems were combined to make up the current patterns shown in Figure 11.

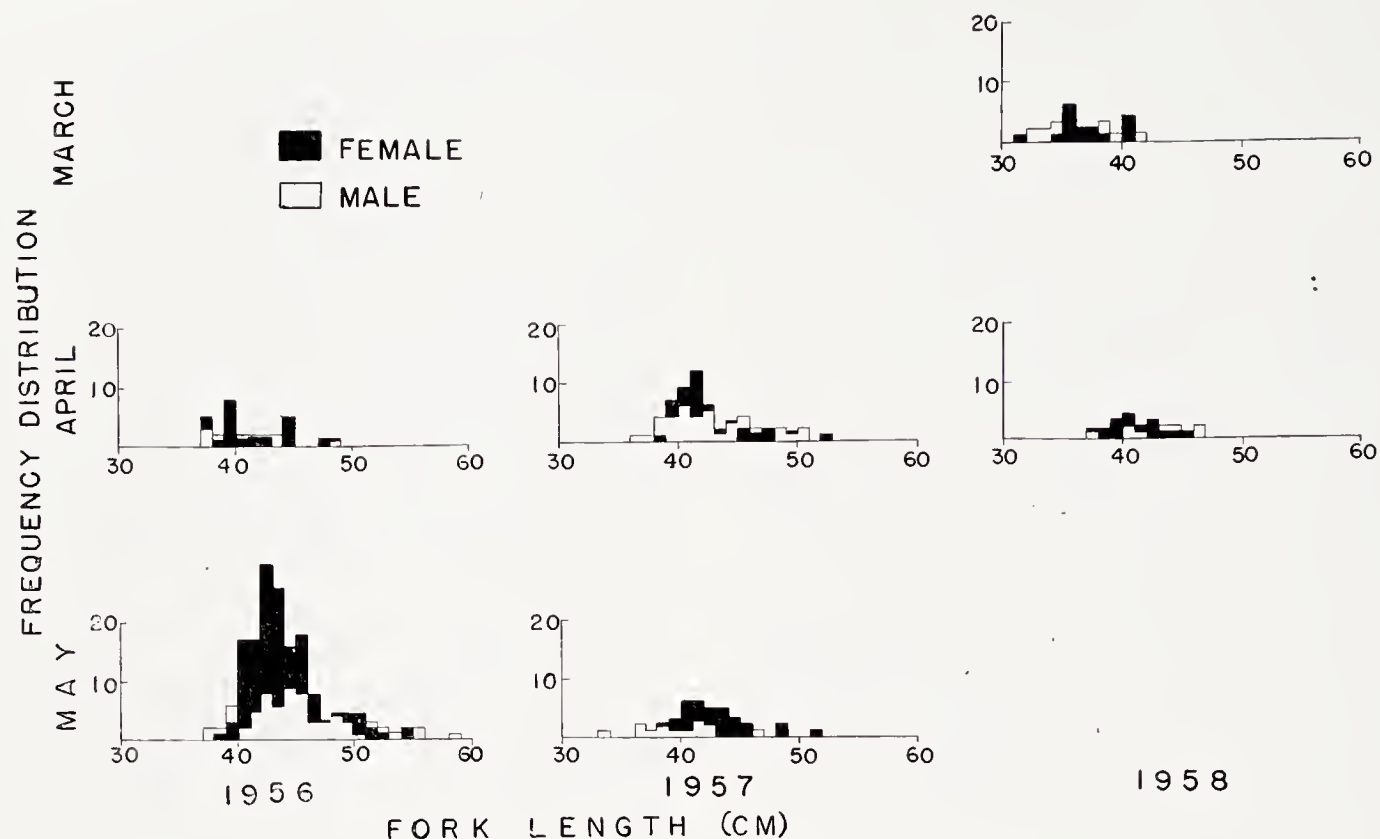


FIGURE 14. Size composition (fork length, in cm) of masu salmon by year, by month and by sex. (Samples were collected by gillnet.)

TABLE 21. Mean fork length of masu salmon by age and sex, March 1960.

Sex	3_2		4_3	
	Fork length <i>cm</i>	Sample size <i>No. of fish</i>	Fork length <i>cm</i>	Sample size <i>No. of fish</i>
Male	38.61	17	44.59	24
Female	38.52	36	42.26	28

the mean fork length for fish caught in March 1960 is given by sex and by age (Japan Sea Reg. Fish. Res. Lab., unpub.). In this case, the males had a greater mean fork length than the females for both the 3_2 and 4_3 age groups. This relationship is just the opposite of that shown by the data collected in 1955 (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956).

Judging from these fragmentary data, it appears that the mean fork length varies from time to time according to sex and there does not seem to be any consistent tendency for one sex to be larger than the other. The data also indicate that there is a tendency for the fork lengths of males to be more variable than those of females. Therefore, it is assumed that

data which make no reference to sex will not introduce large errors in the results. The analysis in the following section makes use of only the combined data, partly because the data available for separate analysis by sex are inadequate.

3.5.2 Change in fork length composition by ten-day period. Data on the fork length composition of the masu salmon caught in the Sea of Japan have been available since 1955 (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956; Japan Sea Fish. Res. Lab., unpub.; and Hokk. Pref. Fish. Exp. Stn., unpub.). These data are summarized by ten-day periods in Figure 15. For this figure, the Sea of Japan was divided into three sub-areas¹¹ as follows: Sub-area 1—south of 41°N and east of 137°E ; Sub-area 2—north of 41°N and east of 137°E ; Sub-area 3—west of 137°E . The divisions of these sub-areas were made after referral to the pattern of fish distribution discussed in section 3.3.1. Most samples were collected by drift gillnets, but a few were collected by trap-nets, longlines or bottom gillnets. The samples that were not taken by gillnet are indicated in the various figures. The size compositions for each ten-

¹¹ The location was not recorded for some samples taken. A sampling area was estimated from circumstantial evidence so that samples could be assigned to appropriate statistical areas.

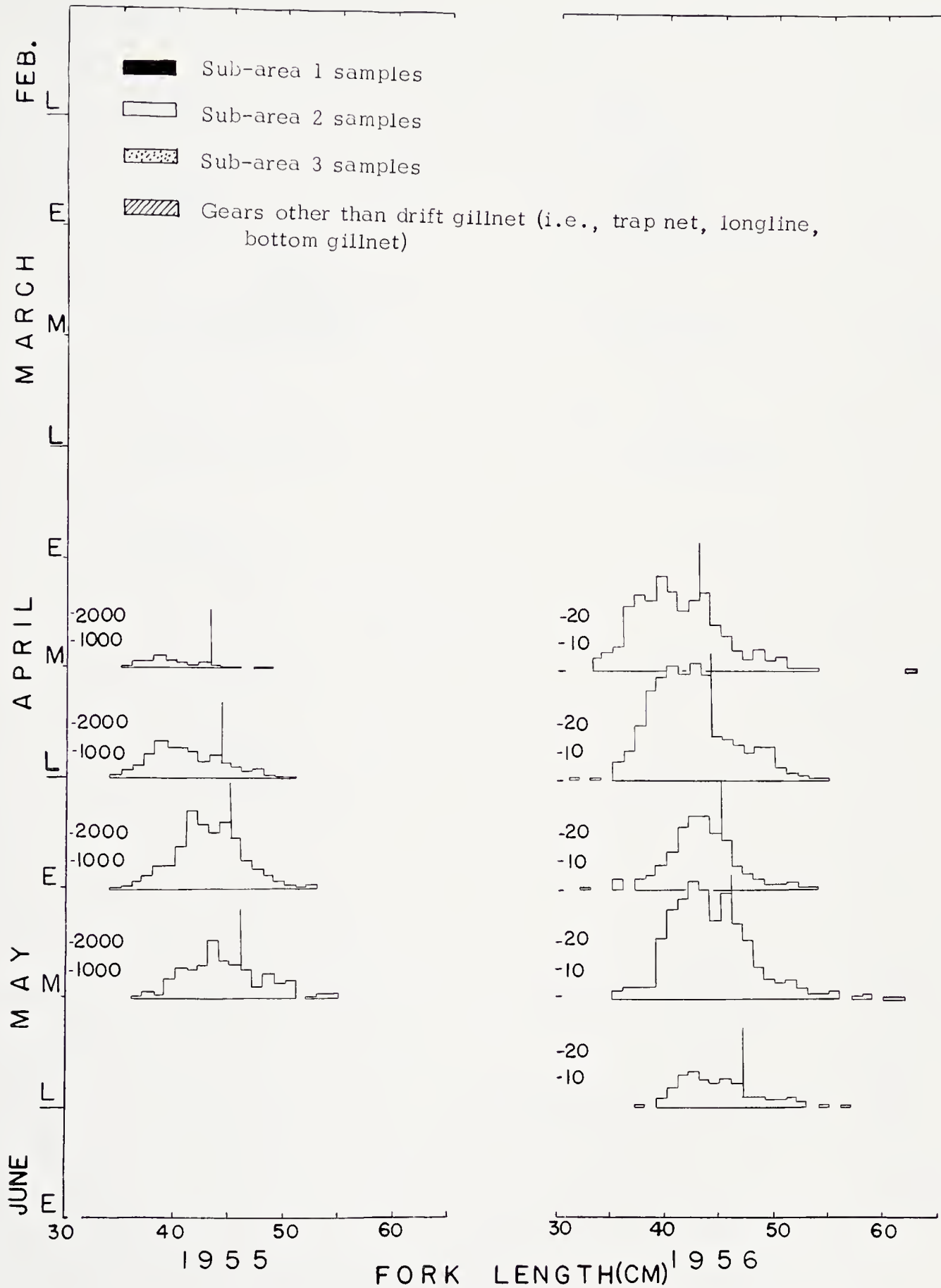


FIGURE 15. Size composition (fork length, in cm) of masu salmon by year and by ten-day period, 1955-1961. Vertical lines indicate seasonal trend in average size increase (see Figure 16). See text, page 116, for definition of sub-areas.

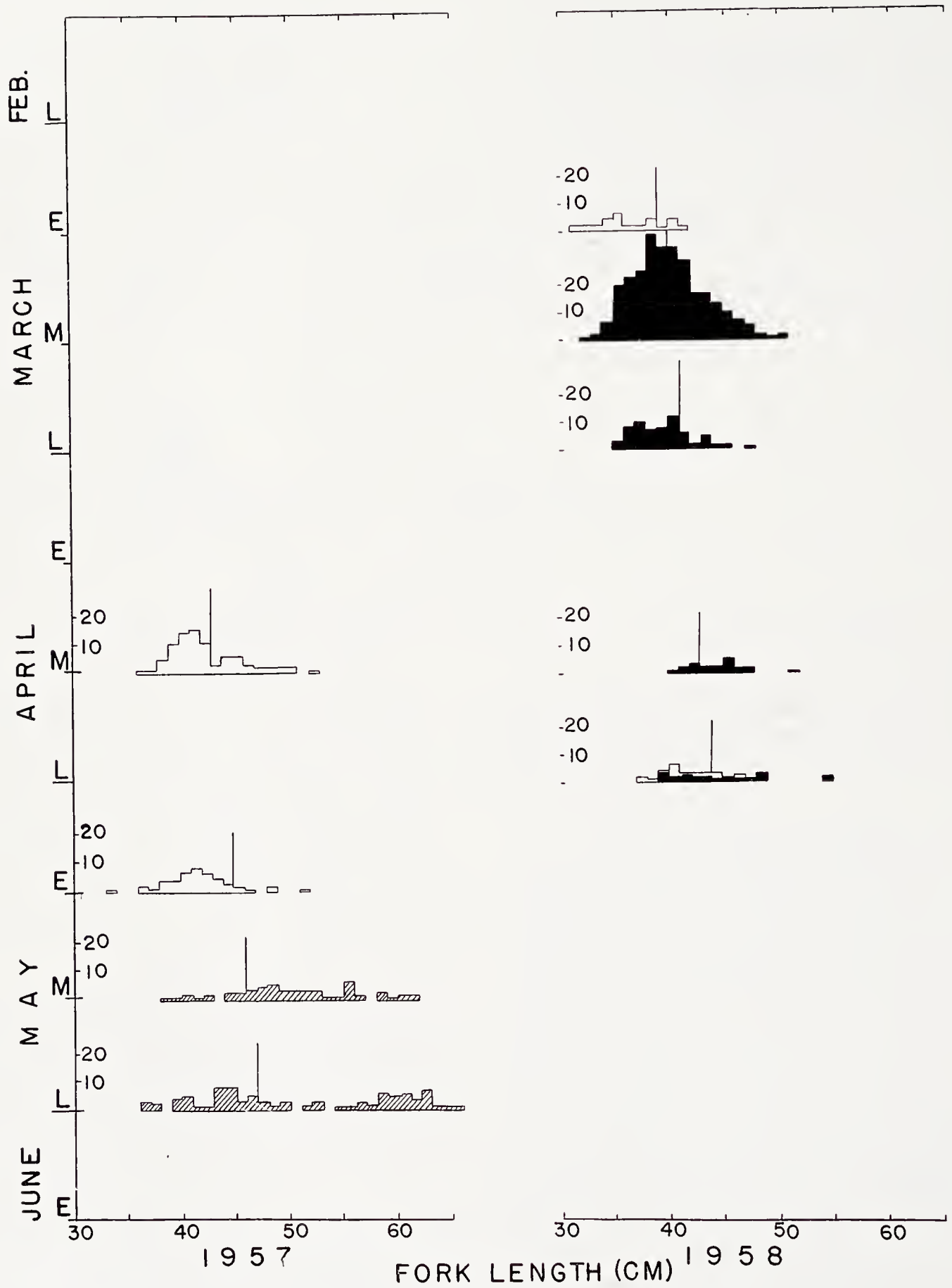


FIGURE 15. Continued.

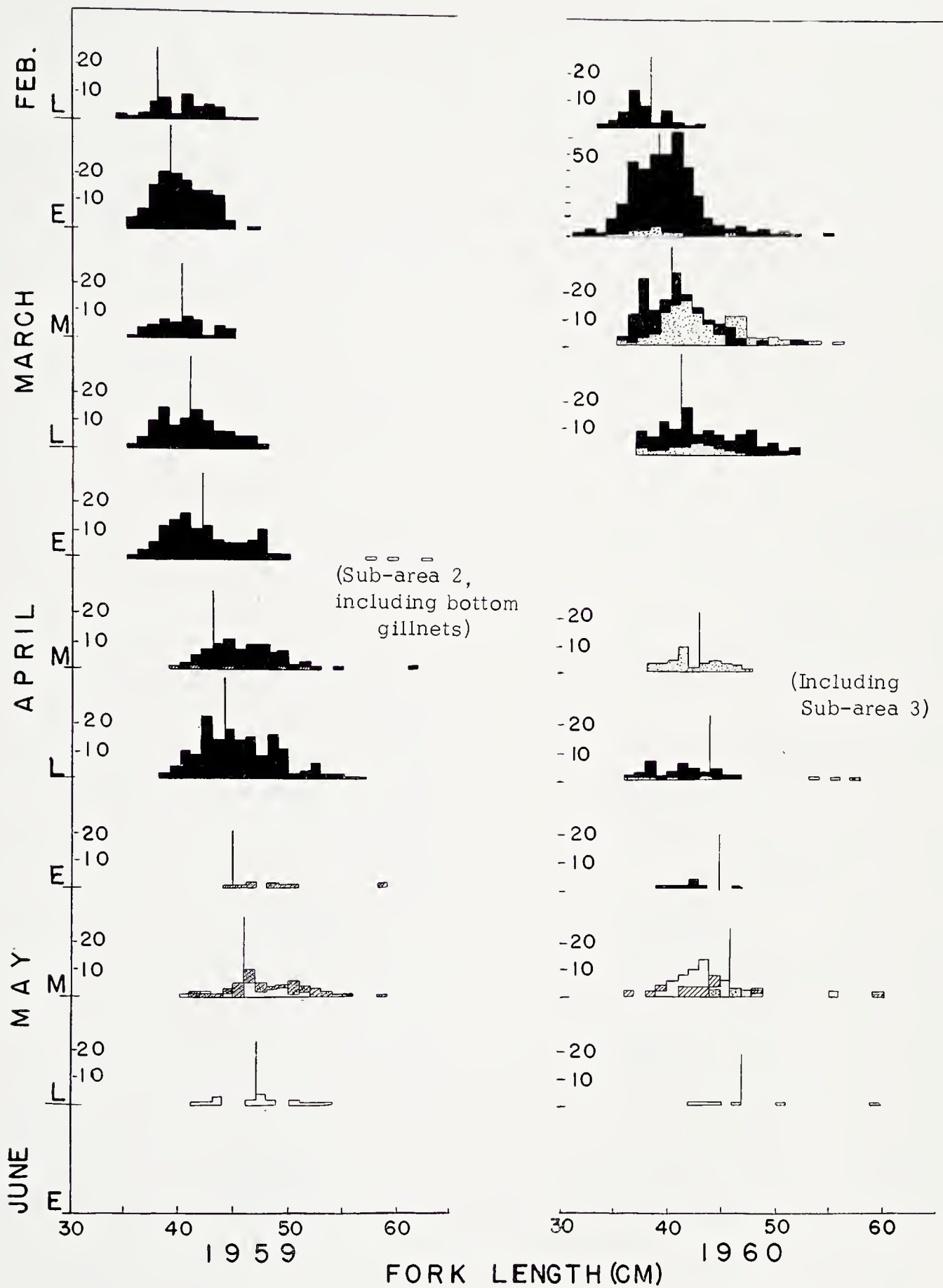


FIGURE 15. Continued.

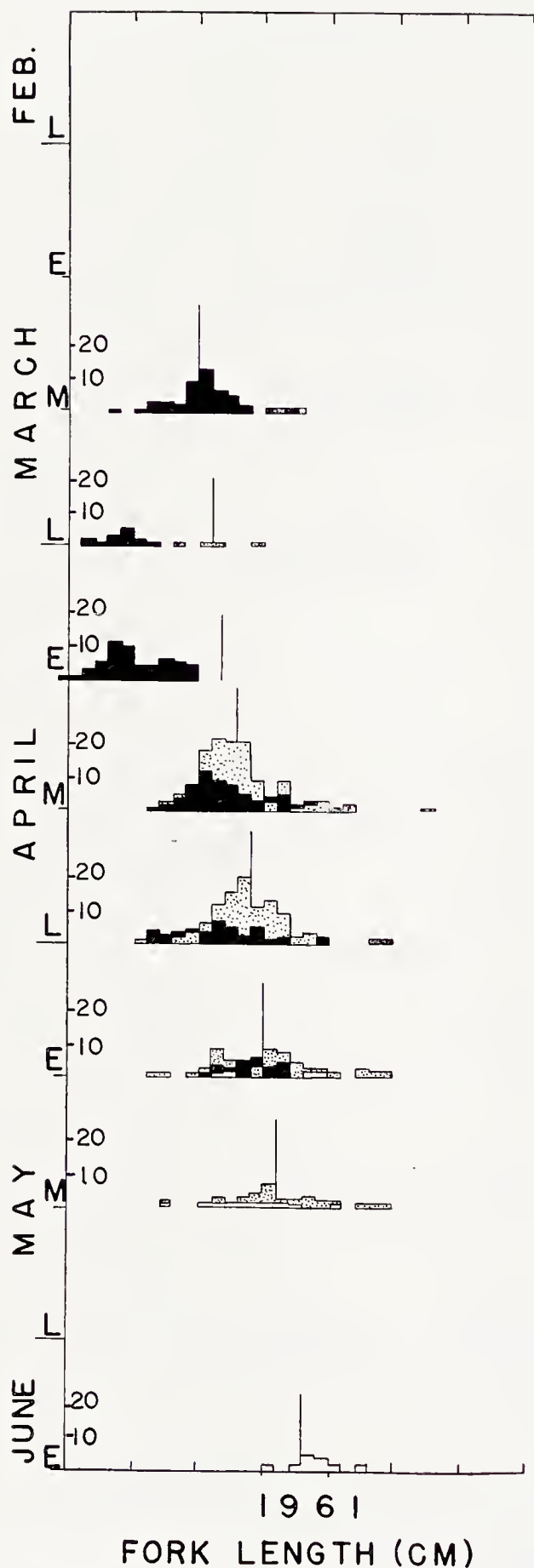


FIGURE 15. Continued.

day period were calculated by taking the total frequency of the fork lengths for all the specimens in all

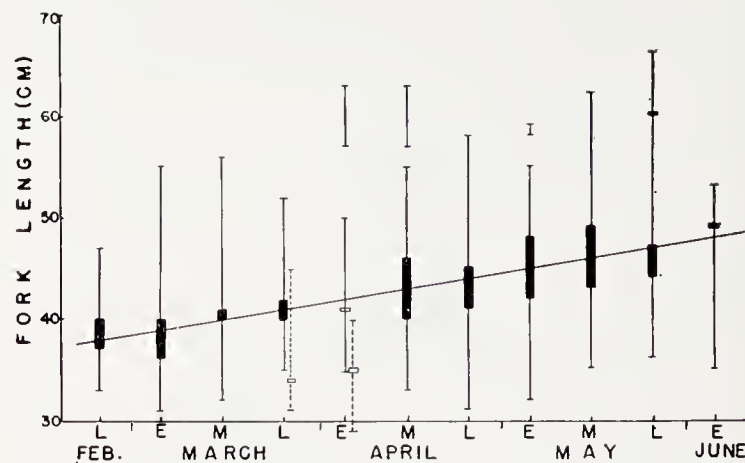


FIGURE 16. The range of fork lengths and the range of modes of fork lengths of masu salmon for the years 1955-1961, inclusive. Dashed lines are for data collected by the *Oyashio-maru* in 1961 (by gillnets of unknown mesh sizes).

samples taken within the period. For 1955, however, the size compositions given by the Hokkaido Prefectural Fisheries Experimental Station and Hokkaido Regional Fisheries Research Laboratory (1956) are used.

It is obvious from Figure 15 that masu salmon are rather small in the earlier part of the season and that they grow as the season progresses. However, year-to-year fluctuations in the size of masu salmon at the same period of the year and sampling period differences in the different years shown in Figure 15 make it difficult to analyze the increase in fish size. The ranges of fork length of all specimens in the samples taken throughout these years and the range of modes for particular years are shown in Figure 16. The data shown in this figure were obtained for each ten-day period by combining all the results given in Figure 15. The data collected by the *Oyashio-maru* (the vessel chartered by the Japanese Fisheries Agency) on March 22 and April 3, 1961, are ignored, since they show a markedly smaller fish size than do the remaining data. With these two sets of data deleted, the increase in fish size during the season is very marked. The increase in fish size is quite linear with respect to time and from late February to early June the length increased steadily from about 38 cm to about 48 cm. The rate of increase in size was about 1 cm per ten-day period, or about 3 cm every month. The maximum fork length also increased linearly and in parallel with the increase in the approximate average fork length. On the other hand, the minimum fork length varied between 31 and 36 cm (29 and 36 cm if the data collected by the *Oyashio-maru* are included) and did not show a marked increase.

Since it is clear that the efficiency of gillnets with a mesh size of 91 mm declines sharply for fish below 35 cm (see Figure 4), it is to be expected that gillnet catches would not contain many fish of such a small size.

It is assumed that the estimated increase in fork length during the season is probably representative of the fish growth. If the trend line mentioned above is assumed to correspond to the actual growth curve, then by extrapolating it the estimated average fork length in early January would be 33 cm and that in late June would be 50 cm. These values do not

contradict values observed for smolts found in the sea nor those for adult spawners returning to coastal waters (see Figure 1).

3.5.3 Annual variation in fork length. Comparison of seasonal variations in fork length composition for individual years with the average trend line of seasonal growth for all of these years combined (Figure 16) indicates that there were large variations in fish size between years. For example, the specimens collected in 1956 were generally smaller than indicated by the trend line, while the samples collected in 1959 included a considerably higher proportion of fish that were

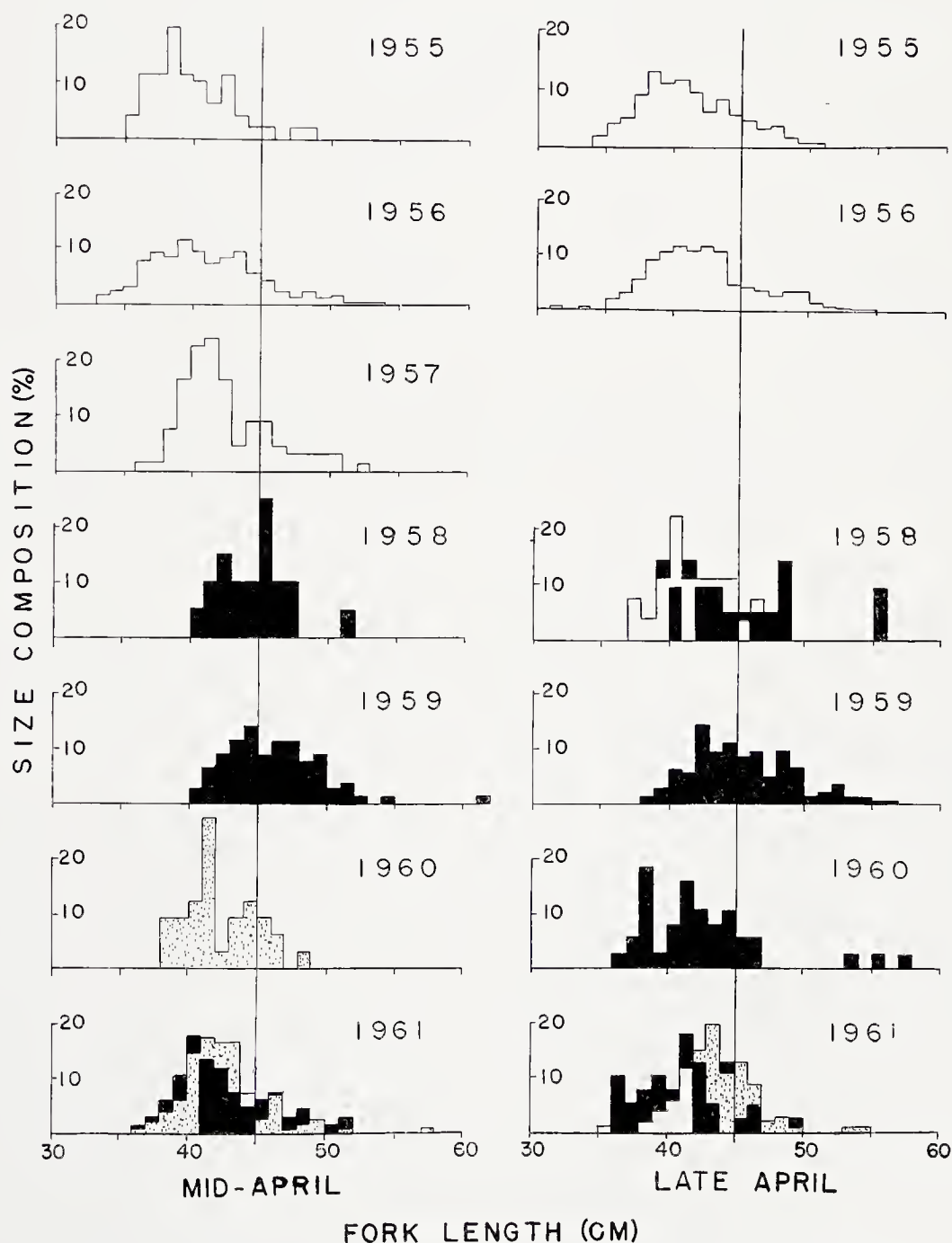


FIGURE 17. Comparison of the size compositions (in percent; size unit, fork length in cm) of masu salmon in various years. See text (p. 116) for definition of sub-areas. Solid histograms—sub-area 1 samples, open—sub-area 2, stippled—sub-area 3.

larger than estimated by the trend line (see Figure 15). In order to obtain information on variations in size from year to year, the size compositions for mid and late April, when adequate samples were usually available, are compared between years from 1955 to 1961, inclusive (Figure 17). The direction of the variation between mid and late April is quite similar for the different years. It is rather remarkable that the fish size was, in general, larger than the average in both of these ten-day periods in 1958 and even more so in 1959, while in 1955 and 1956 the fish size was considerably smaller than the average. In 1957, 1960 and 1961, the fish size was approximately average. It should be noted here that the area from which samples were collected varied according to the year and, as indicated in the next section, some difference was observed in the fork length by area (see also footnote 12, below). The size composition for samples collected in Sub-area 1 is shown by solid black histograms in Figure 17. Even comparison of samples from Sub-area 1 suggested that the fish were larger than the average in 1958 and 1959, while the fish in 1960 and 1961 were smaller. No cyclic variations in fork length such as the two-year cycles observed for West Kamchatkan pink salmon (Taguchi, 1957) were noted.

It is not known whether or not this variation in fork length between years is representative of the difference in growth. As is indicated in section 4.2, the average fish size varies according to which rivers the fish are bound for. Therefore, it is possible that yearly variations in the rate at which different stocks from various rivers are mixing might have produced variation in the fork length composition between years.

3.5.4 Variation in fork length according to area. As is indicated in Figure 15, it seems that there is some variation according to geographical area. It has been noted when comparisons of fork length compositions for the same ten-day periods are made that the fork lengths of fish distributed in the area west of 137°E (Sub-area 3) were often larger than those for fish east of 137°E (Sub-areas 1 and 2). This is interesting because the difference in fork length by geographical area might be connected with the problem of identification of stocks. The aspects referred to above will be dealt with in the following pages¹².

¹² It should be noted that one research vessel may carry gillnets of different mesh sizes from those used by other research vessels. Moreover, the area which was covered by one research vessel might be different from the area covered by another research vessel. Therefore, there is a possibility that these factors would produce some apparent variations in the fork length according to area and mesh size.

Although the sampling program for masu salmon has not been systematic, some samples collected in similar areas at similar times were combined for purposes of comparison, as shown in Figure 18. Since the samples for 1956 and 1957 were taken only off the west coast of southern Hokkaido, and those for 1958 were collected only in the area north to Sado Island, these samples were excluded. The fork length compositions of the combined samples referred to above are illustrated in Figure 19 by histograms for each group by geographical area, by season and by year. In order to compare the sizes of fish between two different geographical areas from which samples were obtained at different times of the season, some adjustments to take into account the time lag can be made by applying an increase of 1.0 cm per ten-day period as indicated by the trend line for seasonal increase in fork length (see section 3.5.2). Since the seasonal increases in the modal fish size are often approximately parallel to the trend line, lines parallel to the trend line are drawn in Figure 19, connecting the positions where the modes occur. The results of the review are outlined below for each year.

In 1959, the size compositions of fish in groups 1 and 3 (Figure 19) are rather similar, while the samples belonging to group 2 had a greater proportion of small fish. Although the inadequacy of the samples in group 4 makes it difficult to compare this group with the other groups, it is assumed that the size composition for group 4 is rather similar to that of group 2.

In 1960, in March, the size compositions for groups 1, 3 and 7 had, when graphed, a rather wide dome-shaped distribution suggesting that these groups contained fish that were a little smaller than the modal size of fish in groups 2, 4 and 5. The size composition for group 6 is quite different from the other groups, as the fish in this group are much larger than those in the others. On closer study, it will be noticed that small fish like those found frequently in group 1 are also found in groups 2 and 6, but that they occur less frequently. It will also be noticed that some large fish of a size which corresponds to the modal size of group 6 were present in fairly large numbers in group 4. Although the sample sizes were rather small and had an irregular size composition, it seems that most of the fish taken later than March correspond to the small fish among the specimens of group 1 taken earlier in the season, when the growth of fish between these two periods is adjusted with the trend line. It is also observed that a few large fish of almost 60 cm in fork length are found in groups 9 and 10.

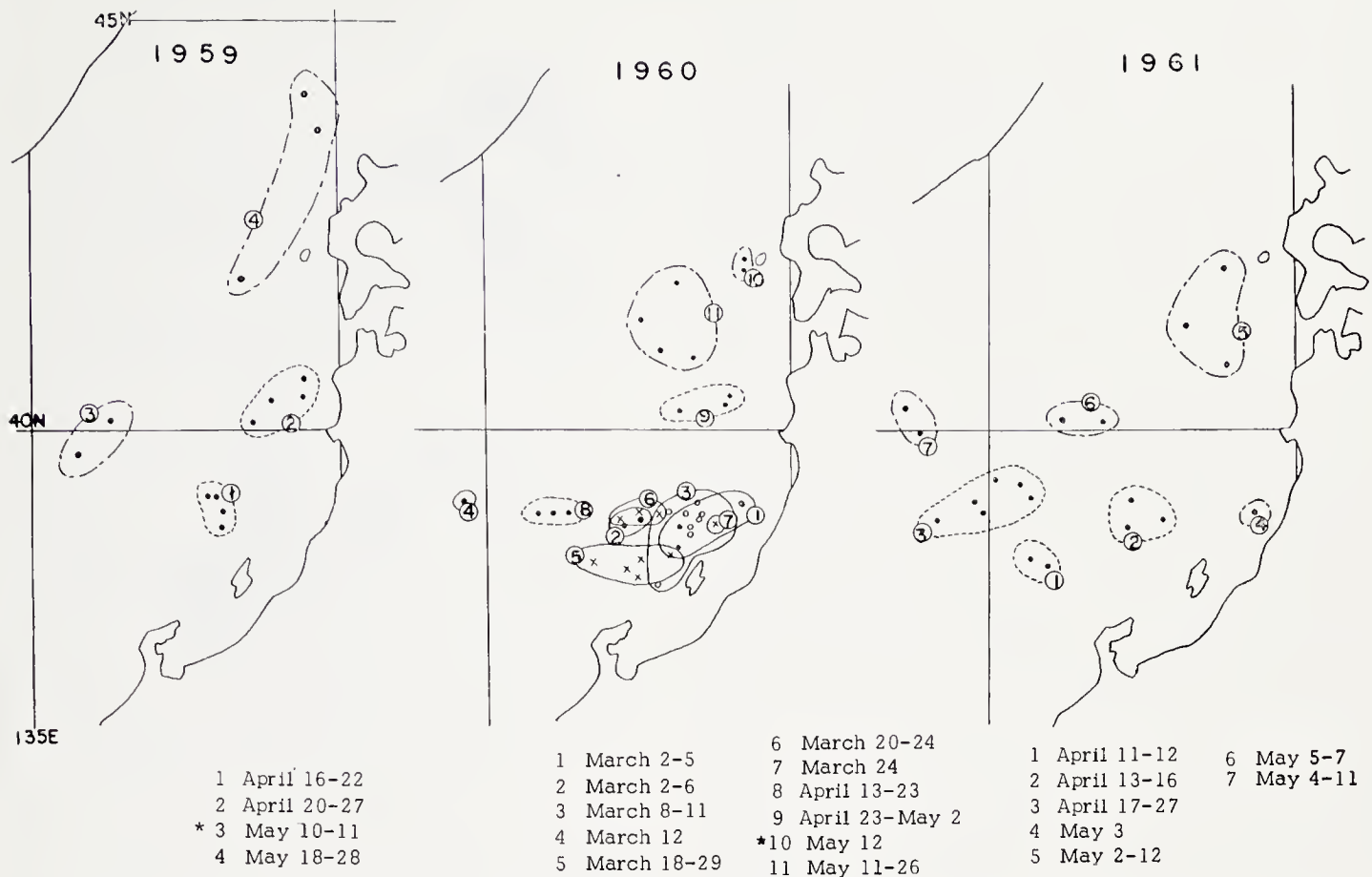


FIGURE 18. Sampling localities and groupings of samples for size composition analysis. (Numerals represent group numbers, for each of which the period of sampling is shown. Samples with asterisks include some fish caught by longlines; otherwise, all samples were taken by gillnets.)

In 1961, the sizes of the individual samples were rather small. The modal size for group 2 is somewhat smaller than that for groups 1 and 3 and the modal size for group 7 is somewhat larger than that for groups 4, 5 and 6.

These analyses were based on information that is rather fragmentary with respect to both time and place. However, they do suffice to give some idea of the complexity of the variations in fish size. The characteristics referred to in this section can be summarized as follows:

(1) Generally, masu salmon found in the northern part of the Sea of Japan to the waters off Hokkaido are small. These small fish correspond to fish in samples from offshore waters in groups 2 and 4 in 1959, groups 9, 10 and 11 in 1960 and groups 5 and 6 in 1961.

(2) Large fish are seen in the offshore area west of 135°E. Fish from group 4 in 1960 and group 7 in 1961 are examples of this.

(3) When the corresponding fork length groups are traced following the time sequence, the statements given below may be made. Fish distributed in the eastern part of the area near Sado Island during March and April are related to those distributed in the area west of Hokkaido in the later part of the season (group 2 is related to group 4 in 1959; groups 1, 3 and 7 are related to groups 8, 9, 10 and 11 in 1960; group 2 is related to groups 4, 5 and 6 in 1961). On the other hand, fish distributed in the western part of the area near Sado Island in March and April are rather closely related to fish distributed in areas farther northwest in the later period (group 1 is related to group 3 in 1959; groups 2 and 5 to group 8 in 1960; and group 1 to groups 3 and 7 in 1961). The one crosswise relationship was observed in 1960 between group 4 and group 6.

The analyses mentioned above suggest some migratory route or intermingling between local stocks. However, further studies are necessary in order to obtain more information.

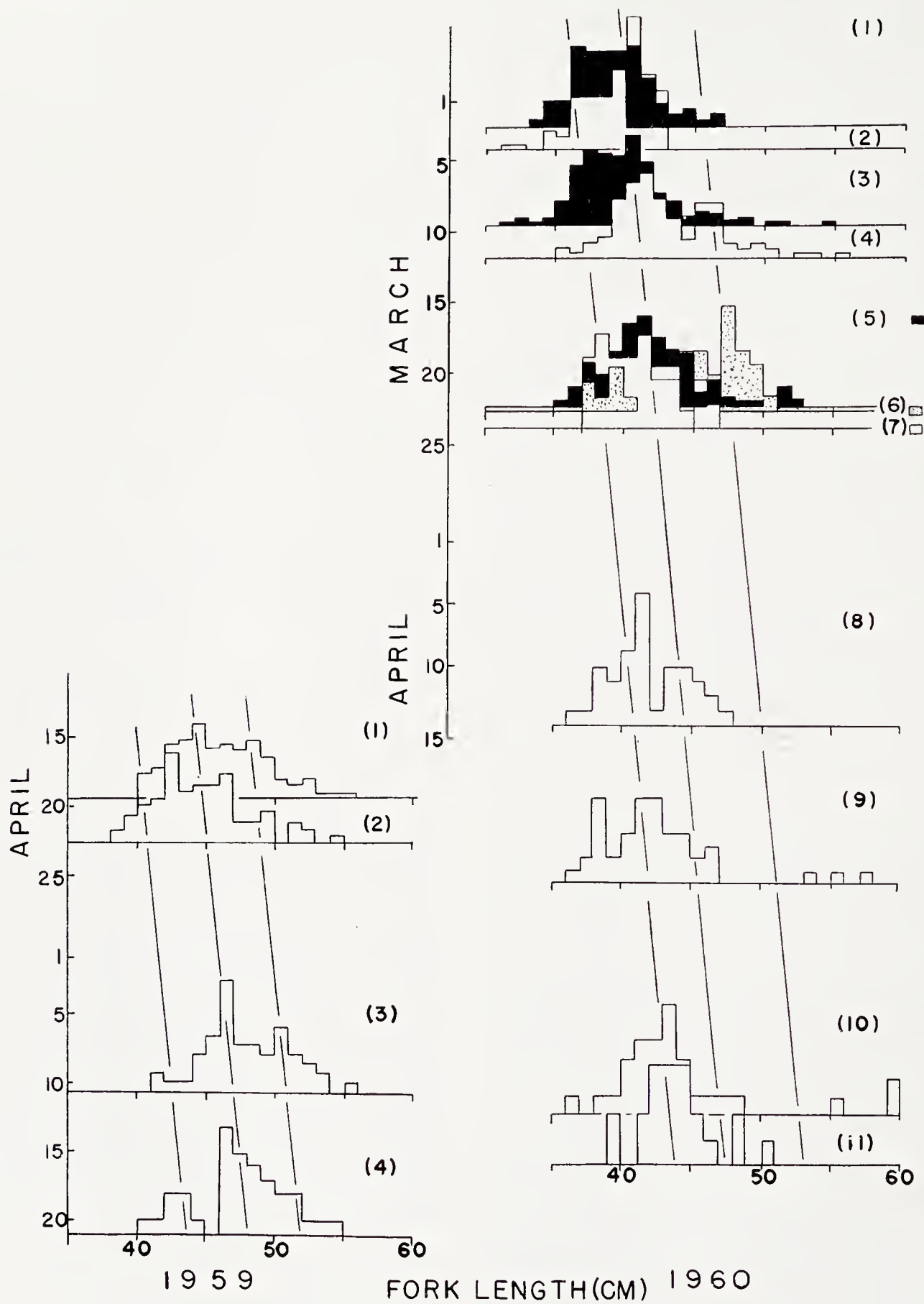


FIGURE 19. Fork length composition of masu salmon in individual groups (see Figure 18). The different designations for the histograms are provided to help identify the overlapped histograms.

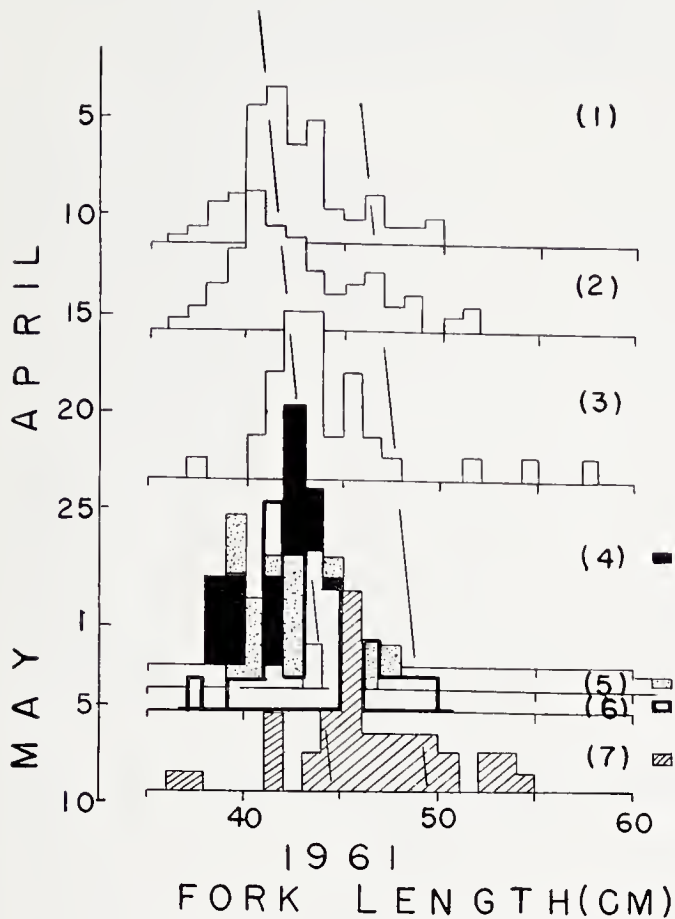


FIGURE 19. Continued.

4. RACIAL STUDIES

4.1 RACES OF MASU SALMON

For masu salmon, there is no published paper on racial studies and only a few tagging experiments have been conducted so far. Moreover, almost no systematic research has been conducted, particularly in offshore areas, on biostatistics which might be used for racial studies. Therefore, it is very difficult to relate the stocks distributed in the offshore areas to those in the coastal areas. In the past, it has been generally accepted that masu salmon did not migrate for a long distance offshore, but stayed in coastal waters all their lives. However, it became clear that masu salmon make as extensive offshore migrations as do pink salmon in the Sea of Japan and that they probably make similar migrations in the Pacific Ocean. Therefore, any studies on the population dynamics of masu salmon require a knowledge of the distribution of the stocks in offshore areas.

Although the biostatistics are rather fragmentary, they do show that there are variations in size and fecundity of masu salmon which can be related to particular coastal areas and streams. The presence

of two types of masu salmon has been known among fishermen and also reported by scientists. One type is ordinary masu salmon and the other is the so-called "itamasu" which is separated from the ordinary type by its greater body depth in relation to its fork length. Also, some scale studies have been made on samples taken from streams as well as offshore fishing grounds. The data available on the racial problem are summarized and discussed in the following sections.

4.2 FORK LENGTH

As has already been stated in section 2.1.5 and summarized in Figure 1, masu salmon collected in streams and coastal waters of West Kamchatka and Sakhalin are rather small. The body length (probably fork length) is approximately 45 cm, on the average, while masu salmon collected from the Amur River are approximately 55 cm in body length and those from the Primorskaia district even exceed 60 cm, on the average. There are some variations in the size of masu salmon between rivers within Hokkaido. The fish from these rivers have average fork lengths which range from approximately 50 cm to 60 cm. There is some general tendency for the masu salmon in streams along the Okhotsk Sea coast of Hokkaido to be smaller than those in other streams of Hokkaido.

It was assumed that the straight trend line which indicated an increase of 1 cm per ten-day period in the modal fork length of masu salmon in the Sea of Japan (see section 3.5.2) was representative of the average growth of individual fish. Next, the fork lengths observed in various coastal areas were adjusted using this trend line to give an estimate of what the fork lengths would have been at times when the fish were thought to be in offshore areas. Then the estimates were compared with the trend line for masu salmon actually collected in offshore waters. This comparison is summarized in Table 22.

It is apparent from this table that generally masu salmon caught in offshore areas in the Sea of Japan correspond very closely to the stocks along the Okhotsk Sea coast of Hokkaido and are quite similar to the stocks of Sakhalin and the small fish of North Korea. The masu salmon from Primorskaia, the larger ones from North Korea and those from the Chitose and Nishibetsu Rivers are much larger fish than those taken in the Sea of Japan. Masu salmon landed at Kamaishi on the Pacific coast of Honshu, Japan, around April 20, 1962, had a modal fork length of 55 cm, which is similar to that for the fish from the Nishibetsu River.

TABLE 22. Estimated fork length of several local stocks of masu salmon at the time of their migration in offshore waters. (The fork length observed in individual areas in coastal waters was used for back calculations to estimate fork lengths in the earlier period, assuming the rate of growth as 1 cm per ten-day period. The figures in brackets are actual measurements in cm.)

Ten-day period	Offshore waters of Japan Sea	North Korea ¹⁾	Primorskaia	Amur River	West coast of Kamchatka	Sakhalin	Okhotsk Sea coast of Hokkaido	Chitose River	Shiribetsu River	Nishibetsu River	
early April	(42)	58	45	58	47	37	39	43	57	47	51
mid-April	(43)	59	46	59	48	38	40	44	58	48	52
late April	(44)	60	47	60	49	39	41	45	59	49	53
early May	(45)	61	48	61	50	40	42	46	60	50	54
mid-May	(46)	62	49	(62)	51	41	43	47	61	51	55
late May	(47)	(63)	(50)		52	42	44	48	62	52	56
early June	(48)				53	43	45	(49)	(63)	(53)	(57)
mid-June					54	44	(46)				
late June					55	45					
early July					(56)	(46)					

¹⁾ As the length frequency of masu salmon had two distinct modes (Yoshida, 1942), two groups are assigned to North Korea.

The fork length composition of the drift gillnet catches of masu salmon in the Sea of Japan varies from year to year and within a particular year there may be a polymodal distribution of fork length frequencies (see Figure 15). Because of this, and because the other types of gear often catch much larger fish, the approximate average straight trend line for growth mentioned above possibly could not be used as a standard for identifying the stocks. In fact, the range of fork lengths observed for samples collected in the Sea of Japan (Figure 16) is wide enough to include the sizes estimated for fish in all stocks during the time of their offshore distribution (Table 22). However, these facts do not invalidate the use of such an analysis as a means of getting some suggestion as to which stocks contribute most to the drift gillnet fisheries in the offshore areas of the Sea of Japan. However, as is the case in Hokkaido, the size of the fish may vary markedly even between rivers within the same area; also, there are yearly fluctuations in the size of fish from the same river, as is shown by the data from Sakhalin (Table 6). For these reasons, more samples are required from coastal waters and streams for the identification of masu salmon stocks.

4.3 FECUNDITY

It is obvious that there is some variation in the fecundity according to the geographical area (see section 2.2.3). Generally speaking, in areas where fish are large, the fecundity of masu salmon is high and conversely, where fish are smaller, the fecundity is usually lower. Fish growth makes it difficult to

compare fork lengths of fish collected in offshore waters and those collected in coastal waters or streams. However, it is assumed that the fecundity of salmon is quite well established by the time the salmon appear in the offshore catches. Therefore, the fecundity of salmon stocks in offshore waters might be an effective index for identifying stocks. However, here again, estimation of fecundity is time-consuming work and results in samples of a rather small size.

Because data on the fecundity of fish collected in the ocean are very scarce, it is almost impossible to identify offshore stocks of masu salmon on this basis. The fecundity of fish collected near Okujiri Island was reported to be 1,230 to 2,937 eggs per female, with an average of 2,040 (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956). The fecundity of masu salmon from the eastern part of the Sea of Japan was recorded as 1,800 to 5,700 eggs per female, with an average of 3,244 (Japan Sea Reg. Fish. Res. Lab., unpub.). The fecundity of masu salmon in the area around Okujiri Island was calculated from 21 specimens collected on April 28, April 30 and May 9, 1955. The fork lengths of these fish ranged from 37.0 cm to 47.0 cm, averaging 41.1 cm. This sample was composed of characteristically small fish with a low fecundity, suggesting that the sample might possibly belong to the stocks of the Okhotsk Sea coast of Hokkaido or western Sakhalin. The fecundity of the masu salmon in the eastern part of the Sea of Japan was calculated from 13 specimens ranging from 44 cm to 58 cm in fork length. These values indicate that fish in this sample were rather large and had a high fecundity. The precise area

from which the samples were taken and the exact time of sampling is not known.

4.4 BODY DEPTH

Some masu salmon, known locally as 'itamasu', have a very deep body. Scale studies of these fish indicate that the growth in their second year of life in the ocean is very marked. In the Horoizumi district of the Hidaka area (Hokkaido), this type of masu salmon (itamasu) is caught only by trap-nets which are set at some distance from shore and have long guide nets. Therefore, it is assumed that the distribution pattern or migration route of such salmon might be somewhat different from that of the ordinary masu salmon. (Ono, 1933.) In the coastal waters of North Korea, two groups of masu salmon were observed, one containing fish with a normal body depth and the other containing fish with a greater than average body depth (Yoshida, 1942). There is no mention of this phenomenon in the literature of the U.S.S.R. There has also been no description of this type of masu salmon in catches

from offshore waters of the Sea of Japan. Therefore, the presence or absence of this type of masu salmon (itamasu) cannot as yet be used as a means of stock identification.

The body height of masu salmon (in cm) is plotted against their total length in Figure 20. This figure is based on data from Yoshida (1942), Hirano (1940) and Kuznetsova's (1954) data on masu salmon smolts. It shows that the proportion of body depth to body length increases as the size of the fish increases. However, separation into two groups by body depth is not recognized among fish of the same length class. Therefore, so far as this figure is concerned the term 'itamasu' would seem to refer to fish which have shown good growth and have reached a length where the proportion of body depth to body length is relatively large. The difference in body depth observed between the two types of masu salmon is probably not a result of differences in relative growth, but is more likely to be due to differences in body length.

4.5 SCALE PATTERNS

4.5.1 Types of scale patterns. Since masu salmon spend one or two winters in fresh water and usually one winter in the sea, the age composition of the run is rather complicated. In addition, the method of aging scales has not yet been standardized among the scientists working on masu salmon. One publication classified the scale patterns of masu salmon into eight types (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956). Initially, the scales are divided into two groups. The first type has one winter check in the freshwater zone and is designated as F_1 and the second, designated as F_2 , has two winter checks in this zone. Some scales of both the F_1 and F_2 types have a so-called "intermediate band" of condensed circuli between the freshwater zone and marine zone. The scales with an "intermediate band" are designated by the letter M. Finally the scales which have a winter zone or annulus in the zone formed during marine life are designated by the symbol S_1 , while the scales with no annulus in the marine growth zone are designated by the letters S_n . Thus, eight types of scales can be obtained by combination of these three types of classification.

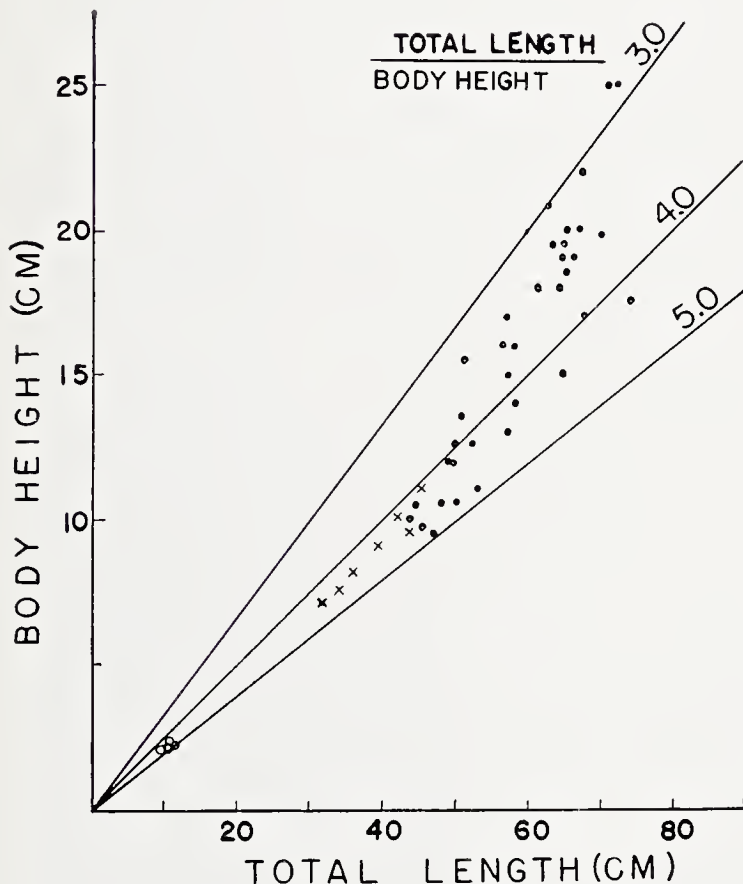


FIGURE 20. The relationship between body height (in cm) and total length (in cm). Solid—North Korea in May (Yoshida, 1942). Crosses—Japan Sea coast of Hokkaido in March (Hirano, 1940). Open circles—Primorskaia and Amur River smolts in streams (Kuznetsova, 1954).

Since this system of classification of scales has not been adopted in the literature published in the U.S.S.R., comparison of scale patterns of masu salmon between the U.S.S.R. and Japan is impossible. Data on scale patterns of masu salmon from streams of Hokkaido (Sano, 1959), from the area near Okujiri Island (Hokk. Pref. Fish. Exp. Stn. and Hokk. Reg. Fish. Res. Lab., 1956) and from the Sea of Japan (Japan

TABLE 23. Frequencies of different types of scale patterns of masu salmon in samples collected from several areas. (See text for the scale patterns.) Figures in parentheses are percentages, others are number of fish.

Area	Month	Types of scale patterns ¹⁾							
		F_1S_n	F_1S_1	F_1MS_n	F_1MS_1	F_2S_n	F_2S_1	F_2MS_n	F_2MS_1
Shubuto River, Japan Sea coast of Hokkaido		(83.7)		(5.4)		(8.9)			
Shinsha River, Japan Sea coast of Hokkaido		(71.0)		(20.0)		(9.0)			
Chitose River, Japan Sea coast of Hokkaido		(7.7)		(92.3)		(0)			
Tokoro River, Okhotsk coast of Hokkaido		(3.6)		(91.0)		(5.4)			
Shari River, Okhotsk coast of Hokkaido		(73.2)		(19.2)		(7.6)			
Near Okujiri Island	April	9	14	28	17	17	15	13	10
		(18.7)		(36.6)		(26.0)		(18.7)	
"	May	7	5	25	14	12	10	14	9
		(12.5)		(40.6)		(22.9)		(24.0)	
The Sea of Japan	March	2	22	2	28	4	32	3	16
		(22.0)		(27.5)		(33.0)		(17.4)	
"	May	2	—	—	2	—	3	2	4
		(15.4)		(15.4)		(23.1)		(46.1)	

¹⁾ The type A scale of Sano (1959) was designated as F_1M , type B as F_1 , and type C as F_2 .

Sea Reg. Fish. Res. Lab., unpub.) are compared here (Table 23).

The outstanding difference between samples from offshore areas of the Sea of Japan and those from streams of Hokkaido is that half or more of the fish in the offshore samples were of the F_2 type, while less than 10% of the fish in the Hokkaido samples were of the F_2 type. In the samples of masu salmon from the west coast of Sakhalin, very few F_2 types were observed. On the other hand, 12 out of 48 fish (25%) sampled on the west coast of Kamchatka were reported to have spent two winters in fresh water (Table 2), but this proportion of F_2 type fish is still far less than the approximate value of 50% recorded for the samples in offshore waters. These discrepancies cannot be explained by the data available. The yearly variations in the age composition of fish in coastal waters or rivers have not been studied.

The proportion of the F_1 type masu salmon with an intermediate band seems to vary between rivers even within the same region. For example, there are considerable variations between the different rivers on the Japan Sea coast of Hokkaido and between those on the Okhotsk Sea coast of Hokkaido. In large streams such as the Chitose and Tokoro Rivers, the proportion of fish with an intermediate band is large (Sano, 1951). The proportion of fish with an intermediate band in samples collected in offshore waters resembles none of the Hokkaido streams, but is somewhere between that of the Chitose and Tokoro Rivers

and that of the other streams. This intermediate proportion can be explained by intermingling, in offshore waters, of various stocks from many rivers.

Some scales collected from masu salmon which have spent at least one winter in the ocean do not have any winter zone. Okada and Sakurai (1937) reported that scales from four out of nine masu salmon (total length—54–63 cm) caught at the estuary of the Ishikari River on May 28, 1936, had no winter zone. Scales without winter zones were also observed among samples collected by the offshore fisheries in the Sea of Japan. Since the data of Sano (1959) are not classified by the presence or absence of a marine winter zone, it is difficult to compare them with samples collected in offshore waters. Of the offshore samples, those from the area near Okujiri Island have a higher proportion of S_n type fish (no annulus in the marine growth zone) than those from the Sea of Japan. The former samples were collected during April or May and the latter were collected mostly in March. This apparently reverse time sequence suggests that the scales without a marine winter zone are not just scales which as yet have not completed the formation of the winter zone. The fact that the scales from some masu salmon caught at river mouths in May did not have the zone also supports this. As suggested by Okada and Sakurai (1937), it might be more feasible to explain the presence or absence of the marine winter zone as due to the differences in environmental conditions of the places where the fish spent the winter.

TABLE 24. The numbers of circuli in the scales of masu salmon.

Area	Age	Number of circuli ¹⁾			Source
		First Year	Downstream migration		
Nishibetsu R., Hokkaido	3 ₂	17	4-5	}	Ono (1933)
" "	4 ₃	10-12	—		
Shubuto R.	"	16.5	—	}	Sano (1959)
Shinsha R.	"	15.1	—		
Chitose R.	"	16.5	6.0		
Tokoro R.	"	16.2	5.2		
Shari R.	"	15.1	—	}	
West coast of Sakhalin					
Ainskaia River, Novoselovskaia River, Kholmsk District—combined	{ Adults, 3 ₂ , Spring	10-14 (11.2)	1-5 (2.4)	}	Krykhtin (1958)
	" 3 ₂ , Summer	8-10 (8.3)	4-6 (5.3)		
	" 4 ₂ , Fall	6-10 (6.8)	7-9 (8.3)		
West coast of Sakhalin, downstream migrants	{ Apr. 22	11-17 (13)	1-4 (3)		
	Aug. 3	6-10 (8.6)	5-7 (6)	}	Kuznetsova (1954)
	Sept. 1	5- 7	7-9 (7.6)		
Primorskaia, Amur	Smolts	4-12 (7)			

¹⁾ Figures in parentheses are means.

Available data on scale types which are related to age of fish do not permit identification of stocks. Some contradicting results suggest that some errors may have been introduced as a result of different criteria applied by each scientist in scale reading. Therefore, some standard techniques in scale reading should be established before any analysis based on scales is started. The problem of developing a standard technique of scale reading is also related to the problem of age determination.

Some scientists from the Japan Sea Regional Fisheries Research Laboratory pointed out that the intermediate band could be assumed to be the first marine annulus observed by Krykhtin (1958) on the scales taken from adult fish which had migrated to sea in the fall. However, according to the unpublished data of Sano, intermediate bands were observed on specimens released in the Chitose River and recovered in the coastal waters a week later. This suggests that some environmental factor such as water temperature or food supply during the freshwater stage from early spring until the downstream migration could cause the intermediate band to form. The Chitose and Tokoro Rivers are rather large streams in Hokkaido and the fact that the samples taken from these streams have a high proportion of specimens with an intermediate band seems to make the theory mentioned above more meaningful.

4.5.2 *Number of circuli.* The number of circuli is often found to be very useful in racial studies of

salmon. This may be because the circuli on the scales are a record of growth, which is a reflection of the different environmental conditions encountered by the fish. Some of the patterns recorded during the earlier part of the life cycle of salmon are particularly useful for racial studies. Some studies on the number of circuli in the first year zone or in the freshwater zone have been made on masu salmon.

The number of circuli on the scales of masu salmon that are within the first year zone or in the freshwater zone are summarized in Table 24. The results show that the number of circuli in the first year zone is much larger for masu salmon in Hokkaido, where it averages 15 to 17, than the values for those from Sakhalin, Primorskaia and the Amur River, which average less than 13. Although the size of the adult fish from Primorskaia and the Amur River is greater than the size of the adults from Hokkaido, the number of circuli formed during their early life is remarkably less. This is good evidence that the number of circuli formed during the first year of life can be used as a means of identifying races.

Unfortunately, no data on the number of circuli on the scales of fish taken in samples from offshore waters are available for comparison with data for the stocks in coastal areas.

5. SUMMARY

1. Masu salmon (*Oncorhynchus masou*) occur only in Asia and waters adjacent to it. They are dis-

tributed along the entire coastal area of the Sea of Japan, along the coast of the North Pacific north of Chiba Prefecture in Honshu, Japan, in the Amur River and along the west coast of Kamchatka. Masu salmon are most abundant in Hokkaido and vicinity. Most commercial catches have been made with coastal trap-nets, handlines or longlines. In addition, in recent years a large amount of masu salmon has been caught with drift gillnets in offshore areas of the Sea of Japan. The annual catches by Japan, including fish taken from offshore waters, are a few thousand metric tons and the annual catch of the U.S.S.R. is estimated to be less than 1,000 metric tons.

2. The timing of the spawning runs to coastal waters varies according to area. Along the coast of the Sea of Japan, early runs occur from February to June, inclusive, in southern areas and later runs occur in May, June and July in more northern parts. In Hokkaido, runs occur in May, June and July. Later runs are observed on the Pacific coast of Japan. As soon as masu salmon appear in coastal waters, the upstream migration of spawners begins in the streams of the area. Adults continue to feed for a time in freshwater streams as they move upstream to the sites where they will spawn during summer and fall. The spawning season in Hokkaido is during September and October.

The eggs usually hatch about two months after they are deposited and fry emerge from the gravel of the spawning beds in the following spring. Most of the fry remain in fresh water for one winter, but a few remain for two. They grow to some extent during their stay in fresh water. The color of the smolts changes to a silvery white the following spring, signifying that they are ready to make their downstream migration towards the sea. The downstream migration of smolts is particularly active during the night. In the streams of Hokkaido the seaward migration is during May and June. The migrants are predominantly female, with the sex ratio being about two females to one male. Thus, it appears that a considerable proportion of the males spend their whole life in fresh water.

It appears that the smolts that have entered the sea stay in coastal waters for a certain period and then gradually leave for offshore waters. Generally speaking, masu salmon migrate in a north-south direction while in the ocean. They move southwards during fall and winter until February or March and then turn back and migrate north until they reach their spawning streams. The southern limit of their migration in the Sea of Japan appears to be some-

where near 38°N and in the Pacific Ocean it is approximately 37°N to 38°N.

3. Most masu salmon are assumed to spend just one winter in the ocean. Therefore, the age at maturity must be 3₂ or 4₃. Commonly, the 3₂ age group is the dominant age group and usually forms more than 90% of a spawning run.

4. The average fork length of fry at the time of their emergence from the gravel is approximately 3 cm. They grow to nearly 10 cm by the end of the following summer in fresh water, but growth stops during fall and winter and their length remains at about 10 cm until the next spring. The length of downstream migrants varies from about 11 to 12 cm (in the U.S.S.R.) or to 15 cm or even larger (in Hokkaido) for fish that have spent one year in fresh water, or about 14 cm (in the U.S.S.R.) for fish that have spent two years in fresh water. Growth is very rapid after the smolts enter the sea. The fork length of masu salmon at the time of their first winter in the ocean is about 30 cm. The fork length of fish which have returned to coastal waters varies from 35 to 70 cm. Masu salmon returning to Sakhalin and Kamchatka are small, averaging 45 cm in fork length, while those returning to the Amur River, Primorskaia and northern Korea are generally large, averaging 55 to 60 cm or more in fork length. Fish which return to Hokkaido are generally large, averaging 55 cm in fork length, while fish which return to the Okhotsk Sea coast of Hokkaido are relatively small. They weigh from 0.6 kg to 6 kg or more at the time of their return to coastal waters. The mean body weight of fish collected in the coastal waters of Sakhalin and Kamchatka is about 1.5 kg, while the corresponding value for fish from the Amur River or Hokkaido is approximately 2 to 2.5 kg.

5. Some males attain maturity within one year after emergence and usually never make a downstream migration. Most masu salmon mature after spending one winter in the ocean. Some development of masu salmon gonads is observed even while fish are migrating in the ocean, but most of the development takes place after fish enter fresh water. From March to May, inclusive, the proportion of gonad weight to total weight for fish maturing in the ocean increases from less than 0.2% to 1% for males and from 1% to 3% for females. This proportion for fish which have just entered the streams is not much different from that for fish taken in the sea, but by the time of spawning in September this proportion for males amounts to several percent and for females it is approximately 20% or more. The

diameter of the ova of fish collected in the ocean is about 2.5 to 4.0 mm, while it is as high as about 7 mm at the time of spawning.

There are considerable variations in the fecundity of masu salmon between individual fish and between areas. Generally, a higher fecundity is recorded for areas where larger fish are found. The average fecundity for masu salmon in Hokkaido is approximately 2,500 eggs per female fish. In several regions of the U.S.S.R. for which data are available, the fecundity varies from less than 2,000 eggs in Sakhalin to 3,200 eggs in the Amur River.

6. Masu salmon are carnivorous throughout their life cycle. While in fresh water, the fry or smolts feed mainly on insects in the water or in the air. In addition, they feed on small fish, including salmon fry. After they enter the sea, they mainly feed on planktonic crustaceans or small fish. Study of the stomach contents of fish from samples collected in the ocean indicated that these fish fed mainly on crustaceans during March and April and on fish and squid during May. This feeding behaviour is somewhat related to the availability of food organisms in the region where the fish are distributed.

7. In the hatcheries of Hokkaido, eggs taken from masu salmon are hatched in spring water at a temperature of 8°C. In hatching experiments on eggs of land-locked yamame, the freshwater-type masu salmon, good hatching rates were observed when the water temperature was between 7° and 11°C. After emergence in the spring, the fry are very active while the water temperature of the streams is increasing through the following summer. During the following winter, while the water temperature is decreasing, they remain rather inactive and are for the most part confined to areas where springs occur. When the snow begins to thaw in the following spring, masu salmon smolts, which are now in their second year of life, renew activity and start their downstream migration.

In offshore areas of the Sea of Japan, masu salmon are usually distributed in places where the temperature of the surface water is approximately 10°C. Judging from the surface temperature of the areas where masu salmon are fished commercially, the temperature range in which masu salmon commonly occur is from 8°C to 12°C. The temperature of coastal waters at the time when masu salmon runs appear in these waters is from 5°C to 12°C around Hokkaido and from 7°C to 12°C along the west coast of Kamchatka. However, in both cases the largest runs appear when the water temperature is around 10°C.

It is assumed that the water temperature of streams to which masu salmon return varies to quite a large extent according to geographical area. In Hokkaido, the water temperature of streams is usually from about 15°C to 18°C at the time of spawning migration. However, since masu salmon spend a certain period of time in the streams before they start spawning, the temperature might reach approximately 20°C during the time that they are in the streams.

8. In offshore areas of the Sea of Japan, drift gill-net fisheries are conducted for masu salmon from March to June. Analysis of catch data recorded for the individual mesh sizes of driftnets indicates that during March a similar fishing efficiency is to be expected when driftnets of mesh sizes between 91 and 100 mm are used for masu salmon. Also, if it is assumed that the mesh selectivity curves obtained for pink salmon adequately represent the situation for masu salmon, then samples taken by gillnets with mesh sizes that are in the range mentioned above are fairly representative for masu salmon between 35 and 50 cm in fork length.

9. Abundance indices of masu salmon were obtained from the catch data and from the data on the cumulative amount of gillnets used in each 20 minute by 20 minute statistical area. In general, the overall abundance of masu salmon is highest during early March and thereafter it decreases at a consistent rate. It is assumed that the emigration of masu salmon from the fishing grounds into the area where there is no fishing activity is responsible for this decrease in abundance. This emigration is in addition to mortality factors and the escapement of fish into spawning streams.

10. In offshore areas of the Sea of Japan, masu salmon are in general distributed between the latitudes of 38°N and 40°N during March; during April their distribution extends to the area off southern Hokkaido; and in May it extends to the offshore areas of northern Hokkaido and, also in May, the southern limit of their distribution shifts northward as far as 40°N. During June, the main concentration of masu salmon passes through the area off Hokkaido and moves farther towards the north. It is assumed that there are two centers of concentration of masu salmon which migrate northwards along 136°E and 139°E, respectively.

Since the relative abundance of masu salmon (number of fish caught per tan) decreases rapidly while the area of distribution shifts northward, it is not appropriate to assume that the fish migrate northwards as discrete schools.

11. It appears that fish are mainly distributed in waters where the surface temperature is between 8°C and 12°C and that fish move northward as these surface isotherms shift northward. On the other hand, the relationship between the distribution of fish and currents and that between the distribution of fish and the vertical distribution of water temperature seem to be very complicated.

12. Since no significant consistent differences between the fork lengths of males and females were found, the analysis of the size of masu salmon was made for both sexes combined. The mean fork length increases through the season. The average fork length during the seven-year period from 1955 to 1961 was 38 cm for late February and thereafter it increased at a rate of 1 cm every ten days until it reached 48 cm in early June. Some year-to-year variations were observed in fork length. For example, in 1955 and 1956, the mean fork length was generally less than the long-term average, while in 1958 and 1959 the opposite was the case. Also, geographical variations even within the same year were observed between the areas from which samples were collected. Masu salmon found in the area off Hokkaido are generally small, while samples taken west of 135°E contain much larger fish.

13. Racial studies of masu salmon have been very inadequate. Insofar as fish size is concerned, fish caught by drift gillnet fisheries in offshore waters of the Sea of Japan are generally small and compare in size to the small fish found along the Okhotsk Sea coast of Hokkaido and Sakhalin and to the smaller fish found in northern Korea. The fecundity of fish caught in the vicinity of Okujiri Island is relatively low and corresponds to the fecundity of fish along the Okhotsk Sea coast of Hokkaido or along Sakhalin. Some masu salmon, known locally as 'itamasu', have a body depth that is extraordinarily deep in relation to their fork length. It is assumed that when masu salmon show a marked increase in size, the proportion of body depth to total length increases.

The age composition of the stocks is such that in offshore waters fish which have spent two winters in fresh water are very abundant (50% or more), whereas most of the fish appearing in spawning runs to coastal waters have spent only one winter in fresh water. The proportion of fish which had spent two winters in fresh water was never as high in coastal waters or streams as it was in offshore areas. The proportion of fish that had scales with intermediate bands between the freshwater zone and the marine zone was variable, within Hokkaido, according to streams. The propor-

tion obtained in samples from offshore waters is a value somewhat intermediate in the range of values observed for the various streams. The number of circuli inside the first freshwater annuli was studied. On the scales of masu salmon collected from Hokkaido, there were, on the average, 15 to 17 circuli in this zone, while the masu salmon from Sakhalin, Primorskaia and the Amur River had less than 13 circuli inside the first annulus. This character could be used in the future for racial studies.

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APPENDIX FIGURE 1. Map of Hokkaido and northern Honshu.



APPENDIX FIGURE 2. Map of the Sea of Japan and adjacent areas.

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